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THE SOILS OF CONNECTICUT

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FOREWORD

The Soils Department of this Station was organized in July, 1923. During the first two years the work was confined largely to detailed soil surveys of selected areas of the state in coöperation with the Economics Department of the Storrs Agricultural Experiment Station in order to ascertain the distribution of the various soil types and their importance in determining the distribution of land cover and the type of agriculture. The work was expanded in 1925 under funds made available by the Purnell Act. Outstanding results of our studies have been reported from time to time in journal papers, press reports, talks at conferences and farmers' meetings, and in the annual reports of this Station. It now appears desirable to present the information which has been accumulating as a bulletin of comprehensive nature.

The results of a considerable amount of soil studies with special reference to forestry problems are not included, since this material is part of a separate bulletin which is being prepared for publication.

The first soil survey by the United States Bureau of Soils was made in the Connecticut Valley in 1899. This was enlarged to include a considerable adjacent area in 1902. A decade later, in 1911 and 1912, the counties of Windham and New London were also covered. However, all of this early work was of a rather general character, many very important soil differences were not recognized, and the location of soil areas on the map was frequently inaccurate. In spite of these limitations, these older surveys have served a useful purpose, especially in the Hartford County area, where the physical characteristics of the soils most desirable for cigar-wrapper tobacco were clearly shown.

Since the discontinuance of their soil survey work in this state, the United States Bureau of Soils (now the Bureau of Chemistry and Soils) has greatly improved its system of classification and the accuracy of the maps, which now cover nearly one-half of the farm land of the United States.

The work is usually done in close coöperation with the soils departments of the state experiment stations and the published reports present detailed soil maps and descriptions of each soil with respect to their natural character and relationships to crops, fertilizer practices and farm values. These reports furnish invaluable information, not only to the individual farmer, but to the extension worker who offers him advice, the research man who studies his problems, the organizations that direct his collective efforts and the banker who loans him money on the value of his land. They are necessary in activities involving policies of land

utilization such as forestry, recreation and wild life. They furnish a physical basis for estimates of road construction problems. In fact, a knowledge of the natural soil factors as pictured by the soil survey is of prime importance in any program relating to an intelligent direction of the future development of all non-industrial activities of the state.

Connecticut, while extremely varied in the minor details of the character of its soils, presents a very simple problem to the trained soil surveyor, on account of its small size and excellent transportation facilities. However, the present topographic map, prepared over forty years ago and relatively inaccurate in detail, is not a satisfactory basis for the accurate location of the various small areas of soil types that occur on nearly every farm. A new topographic map of the state, prepared with the assistance of data obtained from aerial photographs, and printed on a scale of at least one inch to a half mile, would be necessary, but since such a map is seriously needed to meet many other demands of the state, it will doubtless be prepared within the near future.

The material presented in this bulletin, supplemented by other information which will be accumulated in the course of our future investigations, should furnish an excellent basis for the intelligent interpretation of the soil survey when it is prepared. The ground work has been done, which includes the development of an adequate basis of classification and maps already prepared for the equivalent of 20 different towns. It is earnestly hoped that as quickly as a new aeroplane photograph or topographic survey of the state is available, the detailed application of our knowledge of the soil factors in agriculture, forestry and related fields may be made possible through a state-wide soil survey.

The author is indebted to the following persons for their contributions and coöperation in connection with various phases of the subject matter presented in this bulletin:

G. D. Scarseth, former Assistant in Soils Research, and H. G. M. Jacobson, Assistant Agronomist, for soil and land cover maps, laboratory analyses and greenhouse studies.

D. B. Downs, General Assistant, for land cover maps and greenhouse studies.

Mark Baldwin, Inspector, Soil Survey Division, United States Bureau of Chemistry and Soils; G. W. Conrey, Chief of Soil Survey, Ohio Agricultural Experiment Station, and W. H. Latimer, Soil Surveyor, United States Bureau of Chemistry and Soils for soil type identifications and correlations.

I. G. Davis and C. I. Hendrickson, Economics Department, Storrs Agricultural Experiment Station, for economic studies on various soil types.

M. F. M.

PART I

A DESCRIPTIVE INVENTORY OF CONNECTICUT SOILS

Connecticut is a state of diversified agriculture, and the economic trend is in the direction of increased diversification and more intensive use of land wherever possible. The soils of the region are extremely varied in their characteristics, and it is believed that a better understanding of these soil differences and their significance will be of material assistance in improving the adjustment of land utilization to soil.

The specific purpose of this portion of the bulletin is to furnish a "guide-book," whereby the various types of soil can be systematically studied, and to present certain data that indicate the agronomic significance of some of the more important soil differences to be observed.

A detailed soil map of the state cannot be available for a number of years. It is our hope that the material herein presented will enable the reader to recognize the more important soil types and to understand something of their relationships to agricultural use.

Terms Used in Soil Descriptions

It is not possible to describe adequately soil conditions without using a number of terms somewhat unfamiliar to many readers. The following paragraphs are necessary to make the meanings of such expressions more understandable.

Surface soil. The upper portion of a soil in which the mineral soil is mixed with a certain amount of organic matter, and is thus darker in color than the lower layers of soil.

Subsoil. The soil layer underlying the surface soil, and extending to a depth where there is a noticeable difference in character of the material.

Substratum. The material underlying the subsoil, and usually extending practically unchanged to bedrock formations.

Soil horizon. In a scientific study of soils as they occur in the field, the various layers of the soil are designated as "horizons." These horizons are more or less distinct, and are of great significance in showing the conditions under which the soil is developed.

In the regions of the world where the downward movement of water in the soil is practically continuous, such as is the case in all the eastern half of the United States, the soils tend to form

two important horizons. The "A" horizon, the one nearest the surface and immediately below the leaf mold, if such exists, is a zone from which soluble material and the very finest soil particles designated as "colloids" tend to move downward. In all cultivated soils and in some virgin soils, at least the upper portion and sometimes all of this horizon contains enough organic matter to be darker than the lower layers of the soil. Thus there may be both "A_1" and "A_2" horizons, the former containing more organic matter, but both being "A" horizons in the sense described above.

The "B" horizon, occupying a position just beneath the "A" horizon, shows evidence that at least some of the material that has moved down from the "A" horizon has tended to accumulate in this zone. There may be differences in this general horizon, such as in color and clay content, to justify separation into B_1, B_2, etc., horizons.

Below the "B" horizon lies the rock material from which the soil is formed. In Connecticut, except where solid bedrock lies within two or three feet of the surface, this material is usually a mixture of loose stones or gravel, sand, silt and clay in varying proportions, laid down as glacial deposits or as sediments from running water. Such material is designated as the "C" horizon, although not soil in the strictest sense.

Soil color. Soils show many variations in color, and these are frequently valuable aids in distinguishing between different soils. Thirty-one standard soil color names have been selected for use in describing different color variations to be recognized in this state. In order that scientific workers in other states may properly interpret these names, these colors have been analyzed by means of the Munsell color disc method. The results are as follows:

TABLE I. ANALYSIS OF CONNECTICUT SOIL COLORS.

	White (Neutral 9)	Yellow (Yellow 8/8)	Red (Red 4/9)	Black (Neutral 1)
Light gray	45	4	0	51
Gray	36	13	0	51
Cream	34	36	0	28
Yellowish-gray	16	35	0	49
Yellow	4	30	8	58
Grayish yellow-brown	14	23	0	63
Yellowish-brown	6	26	8	60
Yellowish-brown with slight reddish cast	6	21	11	62
Medium brown	11	16	2	71
Medium brown with slight yellowish cast	7	23	4	66
Medium brown with slight reddish cast	9	15	10	66
Dark brown	6	15	2	77
Light grayish-brown	19	20	0	61
Grayish-brown	12	13	0	75

	White (Neutral 9)	Yellow (Yellow 8/8)	Red (Red 4/9)	Black (Neutral 1)
Dark grayish-brown	10	10	0	80
Very dark grayish-brown	9	6	0	85
Black	9	1	0	90
Reddish-gray	32	21	15	32
Reddish-yellow	11	21	19	49
Light reddish-brown	14	17	15	54
Reddish-brown	14	15	13	58
Dark reddish-brown	10	11	9	70
Brownish-red	13	13	21	53
Olive-gray	28	11	0	61
Dark olive-gray	20	9	0	71
Bluish-olive	20	7	0	73
Yellowish-olive	22	18	0	70
Olive-drab	20	15	0	65
Drab	26	17	0	57
Dark olive-drab	16	11	0	72

Soil texture. The texture is determined by the sizes of the soil grains which compose the soil. From this standpoint, the coarse material, larger in diameter than two millimeters (about 0.08 inch), is not included in the calculation. The names applied to the various sizes of soil particles as used by the United States Bureau of Soils are as follows:

TABLE II. THE NAMES AND RANGES IN SIZE OF SOIL PARTICLES.

Separate	Diameter in mms.
Very coarse sand	2.0 — 1.0
Coarse sand	1.0 — 0.5
Medium sand	0.5 — 0.25
Fine sand	0.25 — 0.10
Very fine sand	0.10 — 0.05
Total sands	2.0 — 0.05
Silt	0.05 — 0.005
Clay	0.005 and smaller size

Soils contain varying proportions of particles of all the different sizes. Few soils contain more than 90 per cent of total sands, while even the heaviest clays seldom exceed 60 per cent clay.

For convenience in designating soils with different relative proportions of sand silt and clay, textural class names are used. The following classes occur in this state in areas of appreciable size:

Coarse sand—
Less than 15 per cent silt and clay.
35 per cent or more coarse and very coarse sand.

Sand—
Less than 15 per cent silt and clay.
35 per cent or more very coarse and coarse sand.

Loamy sand—
15 to 20 per cent silt and clay.
35 per cent or more very coarse, coarse and medium sand.

Loamy fine sand—
15 to 20 per cent silt and clay.
35 per cent or more very fine and fine sand.

Sandy loam—
20 to 50 per cent silt and clay.
25 per cent or more very coarse, coarse and medium sand.

Fine sandy loam—
20 to 50 per cent silt and clay.
25 per cent or more very coarse, coarse and medium sand.

Very fine sandy loam—
20 to 50 per cent silt and clay.
35 per cent or more very fine sand.

Loam—
Less than 20 per cent clay.
30 to 50 per cent silt.
30 to 50 per cent sand.

Silt loam—
Less than 20 per cent clay.
More than 50 per cent silt.
Less than 50 per cent sand.

Clay loam—
20 to 30 per cent clay.

Clay—
30 per cent or more clay.

Soil colloids. The extremely fine particles in the soil are called colloids. Due to their large surface in proportion to their weight, they exhibit many important properties not possessed by larger soil grains. They are able to absorb not only moisture but also many important chemical components, such as potassium, calcium, ammonium and phosphate, although apparently able to liberate them to the plant under many conditions. The colloids also act as a cement between the larger particles, and may form a complete coating over the sand and silt grains. They thus cause them to cluster or granulate, and when large in amount may cause the soil to be very sticky when wet, thus making the soils difficult to work. The poor condition produced by an excessive amount of colloids may be partially corrected by organic matter and lime. Soils low in colloids are not retentive of moisture and plant food material, and are lacking in "body." A moderate amount of colloids in proportion to the amount of sand and silt is most desirable.

Organic matter and humus. Plant and animal material enter the soil from the following sources: leaves, bark, twigs and other forest debris; dead grass, roots, stems and other crop residues; the bodies of earth worms and insects; the dead cells of bacteria, fungi and other micro-organisms; applications of animal manures, straw, tobacco stems and stalks, and fertilizers of organic substances such as cottonseed meal, castor pomace or fish scraps. This material in the soil is attacked by bacteria and fungi, thus

gradually decomposing into more or less stable organic compounds of complex nature. All organic substances, in any stage of decomposition, are included in the general term "organic matter," as applied to soils. The well decomposed material, which has lost its original physical and chemical form, is usually called "humus." In a cultivated soil the greater portion of the organic matter is in a humus condition, and is mixed with more or less mineral soil. Well-drained soils contain from 1 to 10 per cent of organic matter in the surface layer, while swamp accumulations, known as peat, may be almost pure organic matter.

Organic matter in soils performs many important functions. It makes a heavy clay soil more easy to till, and increases the retentiveness of a very sandy soil for moisture. It increases the ability of a soil to absorb heat. Aside from these physical effects, organic matter is the food and energy supply for bacteria and fungi and through their activities plant food contained in the organic matter is made available for crop growth. The carbon dioxide set free in the decay of the organic matter greatly increases the solvent action of the soil water on the mineral matter in the soil, thus increasing its availability.

Nitrogen. Closely related to organic matter is the nitrogen supply in the soil. In fact the total amount of nitrogen in the soil is usually about five per cent of the amount of organic matter. Only a small portion of this nitrogen is available for plant growth at any one time. It is released from the decomposing organic matter by the action of bacteria and fungi, and a small amount of nitrogen is taken directly from the air and added to the soil through the action of two important groups of bacteria, one of which produces the nodules on the roots of leguminous plants, while the other is able to fix nitrogen from the air without the assistance of a host plant, when soil conditions are favorable.

Chemical elements essential to plant growth. Carbon and oxygen are obtained by the plant from the atmosphere. Hydrogen and oxygen are furnished by the water entering the plant roots through the soil. The soil also furnishes the plant with the following essential elements: Nitrogen, Potassium, Phosphorus, Sulfur, Magnesium, Calcium, Iron, Manganese, and perhaps others such as Boron, Copper and Zinc, minute quantities of which may play some important part in the life processes of the plant. Silicon and aluminum are absorbed by the plant from the soil in considerable amounts, but it has not been definitely proven that they are required by the plant.

All soils contain these elements. An average soil in Connecticut shows a total amount of all the more important elements sufficient for hundreds of years of cropping. But most of the supply is combined in the soil minerals and slowly decomposing organic

matter in such a way as to permit only small fractions to be available to the plant in the season of its growth.

Three of these elements, Nitrogen, Phosphorus and Potassium, are so often available in insufficient quantities for many crops that they are added in the form of animal manures or fertilizers. The soil may under certain conditions be deficient in calcium, magnesium, sulfur or manganese. The other "essential" elements are almost always furnished to the plant by the soil in adequate amounts.

Soil reaction. Water that is in contact with the soil particles is affected by them, and is either made acid or alkaline or may remain neutral. This property of the soil is called soil reaction. It is one of the most important of soil characteristics, since the degree of acidity or alkalinity is related to a great many other soil processes, such as the liberation of injurious inorganic compounds in the soil, the decomposition of organic matter, the formation of nitrates, fixation of nitrogen from the air, and solubility of nutrient elements such as phosphorus and calcium.

The strength or intensity of soil reaction is now almost universally measured in terms of a scale of figures, known as "pH," in which 7 pH expresses approximate neutrality (neither acid nor alkaline). Six, 5 or 4 pH indicate increasing degrees of acidity, while 8, 9 or 10 pH represent increasing degrees of alkalinity.

Lime requirement. The intensity of soil acidity does not show the total amount of acidity, or vice versa, the amount of lime which must be applied to neutralize completely this acidity. The total acidity depends not only upon its strength, but upon other factors, chief of which are the amounts of organic matter and clay in the soil.

The "lime requirement" of the soil is not usually the same as the lime requirement of the crop, since plants vary greatly in their ability to withstand acid conditions, and many crops are most satisfactory on soils with moderate lime requirement and a slight intensity of acidity. Hence laboratory measurements of lime requirement must be interpreted in the light of the preferences of the crop to be grown.

Common rocks that contribute material for soil formations in Connecticut:

Granite. A grayish-colored, hard, massive rock containing recognizable crystals of quartz, feldspar and mica, as well as other accessory minerals.

Syenite. Light gray or pinkish-gray, hard, massive, composed chiefly of feldspar with smaller amounts of mica and little or no quartz.

Diorite. Dark gray or very dark gray, hard, massive, heavy for its bulk, composed of feldspar, black mica (biotite), and hornblende with little or no quartz.

Gneiss. A grayish-colored, hard, massive crystalline rock, showing evidences of having been changed through former intense heat and pressure

(metamorphism). Shows distinct banded arrangement of the crystals, the bands frequently being highly distorted. Gneiss may be a granite-gneiss, syenite-gneiss or diorite-gneiss, similar in mineral composition to these respective rocks.

Schist. Differs from gneiss in having closely paralleled layers, along which the rock tends to split. Flakes of some of the minerals, such as mica, chlorite or hornblende, are arranged in thin layers or "folia." Schists are designated by the mineral responsible for their foliation as mica-schist, chlorite-schist or hornblende-schist.

Trap. A dark gray, dark brown or nearly black, very hard and flinty rock occurring in characteristic columnar cliffs in many parts of the central region of Connecticut, such as West Peak in Meriden and East Rock, New Haven.

Phyllite. A dark-colored, slaty type of rock, with no noticeable mineral formation, but possessed of a glossy lustre due to minute flakes of mica. It breaks readily into thin plates.

Sandstone. A rock formed from the cementation and solidification of strata of sand and fine gravel, deposited at some remote geologic age. The most common examples in Connecticut are the reddish-colored sandstones of the Connecticut Valley formed in the Triassic Age.

Shale. Also a sedimentary rock, formed in the same fashion as sandstone but of very fine silt and clay material. The rock is thus fine-grained, splitting into thin plates, and has a dull lustre.

Limestone. A sedimentary rock, formed from the deposition of limy substance on the bottom of prehistoric lakes, bays or ocean floor, and later cemented by the carbonate of lime into a rock. The distinctive feature of limestone is the fact that it effervesces freely when hydrochloric acid comes into contact with it. Limestone that becomes crystalline due to metamorphic action is called *marble.*

Causes Contributing to Differences in Soil Occurring in Connecticut

The Character of the Rocks

The geologic past of southern New England has been such as to give us a wide variety of rocks, and the difference in their character has in many cases brought about a marked effect on the soil from which these rocks have been derived.

The greater portion of Connecticut, with the exception of the central portion and included in Areas I and II in Figure 59, represents a complex assortment of crystalline rocks varying from massive gray and pinkish granites and granite gneisses through a wide variation of composition, color and structure to fissile schists which sometimes approach the character of sandstones and which they may have been ages ago, before some titanic disturbance of the earth's crust destroyed the fossil evidences of the true origin of the rocks.

Near the northwestern corner of the state, in a narrow strip along the Upper Housatonic Valley and in the vicinity of Danbury (Area III in Figure 59), marble or limestone rock (the Stockbridge limestone) is found, a relic of submarine calcareous deposits laid down in a far distant past when the highest form of life was

the trilobite, a very strange cousin of the crabs and lobsters that now frequent our shores. With the exception of a very few small and scattered localities in Area IV where thin seams of limestone are found, particularly near Northford, no other calcareous rocks are found in the state. The absence of limestone rock over most of the state has contributed largely to the acidity that is characteristic of most of our soils.

Central Connecticut, and a small area in the Pomperaug Valley (Area IV), have had an entirely different history. At a period millions of years later than when the Stockbridge limestone was formed, and when evolution had proceeded as high as the gigantic reptile forms of the Triassic Age, certain changes in the earth's surface brought this region under water and deposition of sandstone material on the bottom of this body of water began to take place. Climatic conditions and the chemical nature of the water was such as to give a reddish color to the cementing material that developed about these sand grains. The latter were usually composed of small and but slightly weathered fragments of the crystalline rocks of the rugged uplands of eastern and western Connecticut, from which they were washed by torrential streams.

During the same period great sheets of molten rock welled up from far below the surface and either spread out over the surface, with additional deposits of sandstone laid down above it later, or forced itself horizontally from a central fissure between the strata of rock already formed. This lava cooled to form a dark-colored, firm-textured, minutely crystalline rock commonly known as "trap." Great "faults" occurred in the earth's surface, so that the truncated edges of these formations are now exposed as nearly perpendicular cliffs, almost invariably facing in a westerly direction in this state. The chief areas of rock of this type are shown in black in Figure 59.

The Effect of Glaciation

At a period estimated as between 15,000 and 30,000 years ago, the great ice age was in progress. The effects brought about by the advance and retreat of that great sheet of ice must be realized if we are to understand many important differences to be found in the soils described in this bulletin.

That great mass, thick enough to drown the summit of Mount Washington in its icy depths, flowed like so much molasses, yet infinitely slower, down across the northern part of our continent until a climate was reached sufficiently warm to melt it back as fast or faster than it oozed gradually southward. The farthest extent of the glacier in our section of the country was just south of Long Island. Thus the entire area of Connecticut was covered with ice.

In its advance, the glacier scraped over and scooped out the original soil that had probably covered the surface previously, and mixed it with rocks and rock fragments which it dug or snatched from the jagged edges of the irregular slopes. Much of this material was deposited as a thin mantle of "till" from several inches to a few feet in depth, overlying the fresh and unweathered surface of the resistant rock masses beneath. Occasionally the loose material being dragged along under the ice accumulated to considerable thickness, and piled up to such an extent that the ice

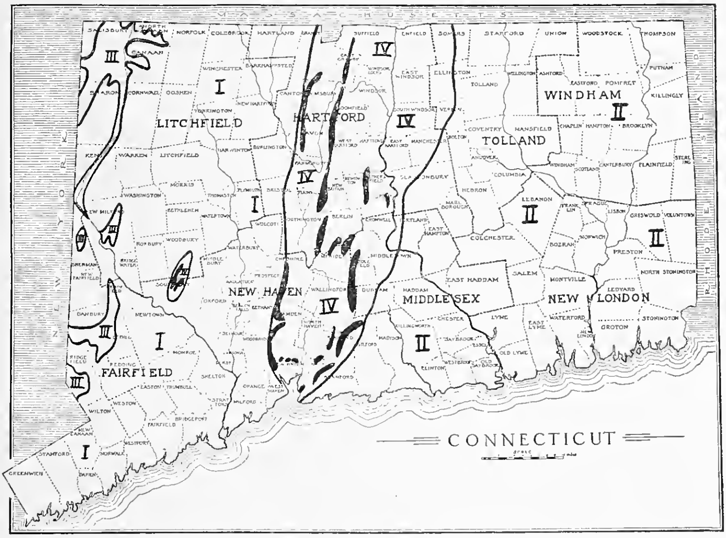

FIGURE 59. Chief physiographic and geologic regions of Connecticut. I. Western Highland of schists and gneiss rocks; II. Eastern Highland of gneiss and schist rocks; III. Western Valleys of limestone rock; IV. Central Lowland of triassic sandstone and shale rocks; black areas—"trap rock" ridges within Central Lowland.

rode over and around it, leaving long, narrow and smoothly convex ridges of material, usually a mile or so in length and about a quarter of a mile wide, rising to a height of from 75 to 200 feet above the surrounding surface. These ridges are called "drumlins." Many occur in the state, particularly in the western portion, as in the towns of Goshen, Litchfield and Bethlehem, and in northeastern Connecticut with best development in Woodstock and Pomfret.

In most cases the greater portion of the material thus spread upon the surface has been derived from rock formations either directly underlying or occurring within a mile or so to the north-

ward. Frequently the influence of a single small outcrop of a peculiarly colored rock can be clearly traced.

The ice sheet at its southermost limit deposited ridges of loose, coarse material highly mixed with boulders, called "terminal moraines." These are not found in Connecticut but at intervals in the melting of the glacier the ice front may have remained nearly stationary for certain periods of time. Thus there were deposited locally, deep and irregular deposits of coarse and comparatively loose morainic material.

As the ice melted, its surface was gradually lowered until the higher hills emerged, and the water released through melting, raced wildly down the temporary valleys thus formed between the edge of the glacier and the hill, frequently piling up irregular hummocks and short ridges of sand and coarse gravel. These deposits are called "kames." In such cases the water from the melting ice flowed for some distance under the glacier, dropping sand and coarse gravel along its more or less serpentine channel. When the ice had all disappeared, the former course of the sub-glacial-stream was left as a long and narrow and winding low ridge, usually rising 20 or 30 feet above the relatively level ground of the present valley floor. These formations are called "eskers." Kames and eskers are frequently found along the valleys of most small streams of the state, particularly those that flow toward the south.

With further melting of the ice, the broader valleys emerged, the lower portions of which were occupied by ice remnants and glacial debris. Extensive, nearly level plains of sandy material were built up by the swollen streams which flowed over these areas. When the ice melted so as to permit an outlet for the water at a lesser elevation, such a plain appeared as a terrace above the general level of the new stream flow. In many cases a series of successively lower terraces were thus formed until the entire valley was cleared of ice. This is the most logical explanation for the extensive areas of sandy soils, containing no boulders or large stones, which occur in the Connecticut Valley north of Middletown, and in smaller belts elsewhere along most of the larger streams of the state.

In some cases, the valley was dammed by the ice-deposited material after the glacier had melted from most of the low-lying lands in the immediate vicinity. In the quiet waters of the lake thus formed the fine silt and clay being washed into it from the melting glacier to the north was gradually deposited. In the summer coarser silt and very fine sand settled out on the bottom of the lake. In the winter, little additional coarser material was supplied because of decreased melting of glacial ice. The fine clay particles which require a long time to settle were then deposited. Thus the clay formations of these glacial lake bottoms show a

"laminated" effect of alternate layers of clay and silt, which record the procession of years during that period. Such clay deposits occur in the Connecticut Valley north of Rocky Hill and in the Mattabesset and Quinnipiac valleys.

When all the ice had melted from the headwaters of our streams, they subsided to their present size. Since then, their occasional floods have deposited some alluvial material on the areas commonly known as "bottomland," especially along the Connecticut River, where the width of such deposits sometimes exceeds half a mile. This recent alluvial material forms soils which are still being periodically changed by new flood deposits. Much fresh sand and silt was added to the Connecticut bottomlands in the great flood of 1927.

Climate

Given sufficient time, the effects of climate on soil formation are such as to completely blot out the differences in kind of rock from which the soils were originally formed. Thus in regions where the soil has been undisturbed for vast periods of time, and where very little erosion and consequent exposure of fresh material from below has taken place, as in many areas in the southern and western parts of the United States, the soil is practically the same, whether originally derived from granite, sandstone or limestone.

Different combinations of rainfall and temperature have thus produced major differences in soils in various parts of the world. In southern New England, regardless of the type of rock or the mode of deposition of the material, all the soils possess certain points of similarity which are distinct from the soils of northern New England, the South, the Middle West, the Great Plains and the arid regions of the Southwest. The soils of Connecticut lie at the border of a Climatic Soil Region and show gradations from the general soil characteristics of the soils of the Middle Atlantic States and the soils of northern New England and Southeastern Canada.

Since the soils of Connecticut are derived from material deposited on the surface by glacial action in geologically very recent time, and the rock material is for the most part rather resistant to the soil-forming processes brought about by our particular type of climate, the climatic effects are not as pronounced as might be otherwise expected.

Drainage

Differences in the rapidity with which percolating waters pass down through the soil, due to the presence or absence of heavier or more clayey substratum, have caused the soils to show corresponding variations in their weathered horizons. A periodical or

permanent waterlogging of the soil reveals evidences of this condition in the soil itself, such as mottled coloration of the subsoil (streaked with rusty, reddish yellow and gray), and the accumulation of more organic matter in the surface soil.

Erosion

Soils on exposed or very steep slopes have been modified by the washing away of the accumulations of organic matter on the surface and the removal of clay, silt and fine sand, leaving the soil depleted in organic matter or excessively stony, gravelly or sandy. While the region was forested, erosion had little effect except on very steep slopes, but since the land was cleared, the soil is frequently much affected.

Clearing and Cultivation

Immediately after the soil is cleared, rapid decomposition of the organic accumulations of the original forest floor begins to take place. This process is often hastened by burning, and goes on more rapidly when the soil is put under the plow, exposing a greater surface to the air and quickening the activities of the micro-organisms of the soil. Erosion is often permitted to take place. Crops are removed. Manure, fertilizer, or lime is added to the soil. The different soil horizons that occur within a few inches of the surface are mixed together. A soil that has once been cultivated or even only cleared and pastured for a few years, is a recognizably different soil for at least a century after it has reverted to woodland, from adjacent areas which have always been in forest.

Connecticut Soils as Compared with other Soils of the United States

As has already been mentioned, climate is the most important determining factor in the broad differences in soil which occur in different regions.

To the north of us, beginning to be fully developed in the higher areas of Litchfield County, lies a region of soils developed under conditions of long cold winters, heavy snowfall, and short, mild summers with abundant rainfall. The soils in their virgin state show a strikingly characteristic profile. (See Figure 60.) Beneath about three or four inches of dark brown, slowly decomposing forest humus there are about two or three inches of a peculiar light gray sandy material (A horizon). Directly under this lie about two inches of dark coffee-brown, firm and compact mineral soil, becoming reddish-yellow-brown and more sandy in the several inches immediately below it (B horizon). The soils of this region possessing the gray layer directly under the leaf

mold, are called "podzol" soils by soil scientists and are classed by the United States Bureau of Soils as the "Canadian Family" of soils.

Southern New England and the region south to Washington, D. C., and westward to the prairies, have soils developed under the action of more moderate winters and warmer summers, with abundant rainfall well distributed through the year. The typical virgin soil (see Figure 60) has a thin, well decomposed layer of

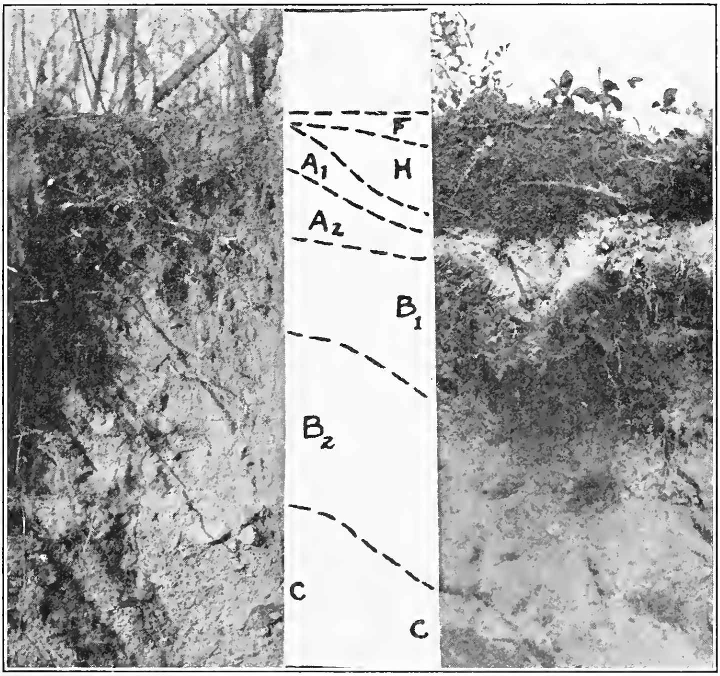

FIGURE 60. Typical non-podsolized or brown forest soil profile of Connecticut (left) and well podsolized forest soil profile of White Mountain region in New Hampshire.

leaf mold resting upon five or six inches of brown mellow loam. Under this the subsoil (B horizon) is somewhat heavier in texture, yellow brown to reddish-yellow brown in color and extending to the depth of 24 to 36 inches from the surface. Below this the substratum (C horizon) is usually of a grayish or grayish-brown color and coarser in texture than the subsoil.

Most Connecticut soils belong in this general group, which is termed the region of "brown forest soils" and classed under the "Jerseyan Family" by the United States Bureau of Soils.

However, there is an evident gradation toward the "Podzol Soil" character in many areas, particularly in northern Litchfield County. Besides this, the resistant character of the rock material and the relatively short time since glaciation have given the soils of Connecticut a somewhat different character than is typical of the climatic soil group.

In the South we have red and yellow soils, in the eastern prairies black soils without lime hardpan, in the western prairies black soils with lime hardpan, in the great plains "chestnut-colored" soils, and in the arid regions the desert gray and brown soils. All these soils are strikingly different from any of the soils of Connecticut, but their characteristics need not be described here.

General Description of the Topographic Features of the State

Connecticut is usually divided into three distinct physiographic regions. A central belt, extending north and south, about 20 miles wide at the Massachusetts border, and narrowing to five miles at New Haven, is known as the "Central Lowland." That part of the state west of this belt is called the Western Highland, while the area east of it is designated the Eastern Highland. In northwestern Litchfield County and in the vicinities of Danbury and New Milford an area should also be recognized which might be called the "Limestone Valleys."

The Central Lowland is characterized by a general low elevation, ranging from an average of about 50 feet at New Haven to about 200 feet at the Massachusetts border. Narrow belts of pronounced trap-rock ridges, extending in a general north-south direction, with sharp cliffs on their western faces and gentler slopes toward the east, rise to heights of from two to 400 feet above the adjacent lowland.

There are three general areas in the Central Lowland where extensive stretches of level or nearly level plains are to be found. The largest of these is in the Connecticut River Valley north and east of Hartford, in the Farmington Valley between Plainville and Southwick, Mass., and in the Quinnipiac Valley between New Haven and Meriden. Elsewhere the country is rolling to moderately hilly.

The Western Highland rises abruptly from the western edge of the Central Lowland to about 200 feet just west of New Haven and about 800 feet at the Massachusetts line. Toward the northwest there is a general rise to more than 2,000 feet at the northwestern corner of the state.

There is a considerable local range in elevation, and the greater portion of the region is hilly to mountainous in relief. Exceptions

to this are extensive areas where the uplands flatten out into long ridges with smooth outline and more gentle slopes. These ridges are of a uniform character, with their longer axes about three-quarters to one and one-half miles long and from one-quarter to three quarters of a mile wide. These have been previously described as drumlins. The most extensive development of this type of topography is in central Litchfield County.

The Limestone Valleys, lying within the Western Highland region, are from 200 to 1,000 feet lower in elevation. This is due to the more easily weathered type of rock. The topography is rolling to moderately hilly, in sharp contrast to the adjacent mountainous slopes.

The Eastern Highland rises abruptly from the eastern edge of the Central Lowland. The elevations are in general somewhat lower than in the Western Highland, ranging up to about 1,200 feet. Mountainous topography is only local in occurrence, and for the most part the surface is hilly, with a marked irregularity of relief. Since the hills are smaller than in northwestern Connecticut, there are many more of them in a given area than in northwestern Connecticut.

The drumlin type of topography occurs to a more limited extent in the Eastern Highland. Hills of this sort are numerous only in the vicinity of Woodstock, Pomfret and Lebanon. Isolated drumlins may be found elsewhere, but they make up a small proportion of the total area.

In the Eastern Highland region many of the valleys are partially or completely occupied by gravelly mound-like knolls of the "kame" type, with occasional narrow serpentine elevations called "eskers." The best development of such topography is in the Natchaug and Quinnebaug valleys. It occurs in the Western Highland in local areas only.

In both the Eastern and Western Highlands the larger streams may have level, sandy terraces at intervals along their courses. Flood plains are narrow and of small importance along the smaller streams of the highlands, and the only flood plains of any considerable size are those along the Connecticut River, in the portion of its course that lies in the Central Lowland.

Small inland swamps and bogs of from 10 to 500 acres in size occur in almost every town. Their total area amounts to about three per cent of the state.

Along the shore of Long Island Sound many tidal marshes are developed. As fingers these may extend two or more miles inland, and they are sometimes 1,000 or more acres in size. Frequently the tidal swamp is separated from the sea by narrow belts of sand thrown up by the waves and blown inland by the wind. The area of such formations is insignificant, being occupied almost entirely by shore cottages.

Chief Characteristics and Geographical Distribution of the Important Soils of Connecticut

In order to obtain accurate information as to nature of local soil differences, and to study the distribution of crops, pastures and forest on the various soils, careful field surveys have been conducted on areas in the state represented in Figure 61. Maps were prepared on the scale that one inch equals one-half mile, which permitted the correct representation of all areas of soil larger than about two acres. However, since many fields contain "spots" of noticeably different soil that are only a few square rods in extent, absolute accuracy in soil mapping in a region of such great local diversity could never be attained without exorbitant cost in the preparation and publication of maps of a scale of such size.

Until financial provisions have been made for the complete survey of the state in reasonably accurate detail, the maps of the areas already covered will be kept on file for the reference of interested persons, but their publication will not be attempted.

However, from the information obtained in the course of these surveys, supplemented by extensive reconnaissance over the entire state and by thorough study of existing maps showing the topography, geology and forests, we have prepared an Outline Soil Map, which accompanies this bulletin.

This map is in no sense an attempt to show the exact local variation in soils. It is designed to represent the major areas of the main soil types of the state. The state is divided into areas designated as soil groups which are named from the characteristic soil that may be found within the area represented on the map. Many other soil types besides those thus named are known to occur, but these are ones that are naturally associated or closely related in their more important properties to the types named as the soil group.

In the key to the soil types of the state presented in another section of this bulletin, the soil group on which these various types may be expected to occur is indicated by the appropriate letter symbol.

Gloucester fine sandy loam group. (Map symbol G.) These soils are developed on more or less hilly topography. Boulders and angular rock fragments are always present, but not sufficiently numerous to prevent the improvement of 30 per cent or more of the total area. They are light-textured, medium brown surface soils, with light yellow-brown subsoils developed from moderately deep, stony, coarse and uncompacted glacial till of predominantly grayish color.

As the map indicates, they include the soils of most of the Eastern Highland, and of the southern and western portion of the Western Highland. Rock outcrop frequently occurs. Boulders

are frequent, although the more stony areas are assigned to the Stony Soil Group. Cultivated fields were formerly much more stony, but have been partially cleared of stone to be utilized as fences or road material. The rock material is predominantly gray in color, due to the high percentage of quartz and light-colored feldspars.

Underdrainage is rapid because of the open, porous character of the underlying material. Surface drainage is excellent, due to the irregularly hilly topography. The surface and subsoil are of fine sandy loam, or more rarely, a light loam texture, giving good mechanical condition.

FIGURE 61. Typical landscape of the Western Highland, with Charlton soils on the hills in the background, Hinckley soils on the low gravelly knolls in the middle distance, and irregular slopes with Gloucester soils in the foreground.

When not too stony for easy cultivation, good yields of corn, potatoes and vegetable crops are obtained. Grass hay is the chief crop, although yields are light and of poor quality because of the leachy character of the soil. Fields are of small size, and difficult to operate on account of frequent large boulders and the irregular surface. The wooded portion and much of the pastured area of the farms are usually quite stony.

Charlton loam group. (Map symbol C.) Such soils occur on the more smoothly rolling hills of the Eastern and Western

Highlands. Large boulders and rock fragments of various size may be found, but are usually less abundant than in the Gloucester fine sandy loam group. The surface soils are grayish-brown loams and fine sandy loams, with yellowish-brown, yellowish-olive or light brown subsoils of slightly heavier texture, developed over deep, very compact glacial till ("boulder clay" or "hard-pan") of yellowish-olive, grayish-olive, or light brown color, containing from five to fifteen per cent of actual clay in most cases. The presence of this sort of substratum within about two feet of the surface has a marked effect in decreasing the rapidity of under-drainage and the retentiveness of the soil for moisture and soluble plant nutrients. Reasonably favorable topography and degree of stoniness permit larger fields upon which modern tillage and harvesting machinery can be used. In many cases the soils are slow to dry out and warm up in the spring and are regarded as "late" for some market garden crops. Commercial orcharding is extensively followed, but dairying is the leading enterprise, as a result of the favorable conditions for grass hay and silage corn.

The largest areas are in the Western Highland, although commonly occurring in the vicinity of Woodstock, Pomfret and Lebanon, as well as locally in several other eastern Connecticut towns.

Wethersfield loam group. (Map symbol W.) Over the hilly portion of the central lowland of Connecticut, the soils are closely related to the reddish-colored sandstones and shales which here form the bedrock material. Slabs and chips of this rock are common in the soil, but large boulders are of infrequent occurrence. A reddish cast is commonly observed in the brown color of the surface soil. The subsoil is reddish yellow-brown or red-brown, over a thick and usually compact substratum of sandy loam or sandy clay, which contains much decomposing red sandstone and shale material.

The topography is usually favorable for cultivation and a wide range of crops is commercially grown. Market gardening, dairying and orcharding are equally successful, while there is some use of these soils for tobacco in the Hartford County tobacco district.

Dover fine sandy loam group. (Map symbol D.) In the limestone areas of northwestern and western Litchfield County and in northwestern Fairfield County on the rolling hills overlying such formation, a sufficient amount of lime exists in the parent material to form soils that are noticeably less acid than is natural for other soils of the state.

The surface soils are of a medium brown color, with yellow-brown subsoils over a rather sandy substratum containing noticeable amounts of disintegrating white marble fragments. There are usually some boulders of gneiss and schist rocks, and the areas

also include many soils of the general type described as Charlton fine sandy loam. Exposed limestone ledges occasionally prove an obstacle to cultivation, but on the whole the soil is of excellent character for hay and corn, vegetable crops, potatoes and grazing.

Hollis loam group. (Map symbol I.) These soils occur only in the towns of Woodbridge, Orange and Milford, where they are closely associated with the underlying bedrock of phyllite and chlorite-schist. The topography is gently to strongly rolling. Boulders are infrequent, although the soils contain many "chips" of shale and slate fragments of a dark bluish or greenish-gray color. The surface soils are dark grayish-brown, with yellowish-olive subsoils over glacial till and weathered bedrock composed chiefly of a mass of dark gray shale and slate fragments. The soils are heavier in texture than most other upland soils of the state, heavy loams and silt loams being the rule. They are well adapted to grazing, hay and corn, although usually heavy lime and fertilizer applications are required.

Enfield very fine sandy loam group. (Map symbol E.) In certain towns of Hartford County, especially in Enfield, East Windsor, South Windsor and East Hartford, there are low, rolling hills of a soil of exceptionally fine sandy texture. The material forming this soil is believed to have been deposited by wind action during a period at the close of the ice age, laid down as a layer from two to five feet thick of very fine sand and silt over the older surface, which was either compact glacial till or water-deposited sand and gravel. From such deposits a soil has been formed that is entirely free from coarse sand, gravel, or stone, and that contains an unusual proportion of very fine sand. The surface soil is light brown in color, while the subsoil is grayish-yellow-brown. There is a complete absence of stone, gravel and coarse sand in both surface and subsoil, although the underlying substratum may be quite stony or gravelly. Such a soil has an almost ideal physical condition, being quite absorbent of moisture, easy to cultivate, and with adequate fertilization high yields of crops of excellent quality are obtained in years of normal rainfall. A very high percentage of the soils is in cultivation. Tobacco is especially favored. Good results are obtained with both vegetable crops and general field crops. Exceptionally good potato fields are found on these soils. The humus content is somewhat lower than for most other soils of the region.

Manchester sandy loam group. (Map symbol N.) These soils occur in the Central Lowland division of the state with considerable areas in many towns. They are most often associated with the smaller valleys, but commonly occur on belts of strongly rolling to irregularly hilly relief, which follow the same general topographic level for many miles as fringes around the main

drainage basins of the Connecticut, Farmington and Quinnipiac rivers.

The typical condition is a moderately gravelly sandy loam surface of dark brown color, with reddish yellow-brown subsoil, over coarsely stratified sand and gravel of light reddish-brown color, composed chiefly of red sandstone and shale material. When not too steep or gravelly, the Manchester soils are well suited to tobacco, early vegetable crops and potatoes. Corn does fairly well when heavily fertilized. Grass hay and pasture sods are commonly thin as compared to the less leachy "Wethersfield" soils of the region.

Hinckley gravelly sandy loam group. (Map symbol H.) These soils are very common in both the Eastern and Western Highlands, but find their most extensive development in the Quinnebaug and Natchaug valleys. They occur in narrow belts or isolated patches at varying heights above drainage levels in practically every sizable valley in the highlands. The topography is frequently quite irregular but as a rule they occur along the same general level in any particular valley. No large boulders occur, but rounded "cobbles" of considerable size are common.

The surface soil is brown in color, with a yellow-brown sandy and gravelly subsoil, over a coarsely stratified sand and gravel substratum composed chiefly of igneous and metamorphic rocks.

The texture of the soil is quite variable and a single small field may include a half dozen different soil classes. Normally the more gravelly and sandy soils occur on the knolls, while more loamy soils of darker color are to be found on the lower slopes and depressions.

Where the land surface is not too steep and the fields include only small patches of the excessively gravelly or sandy types, these soils are well suited to early crops. Field corn and grass hay are severely injured by drouths and alfalfa is the most promising hay crop. Pasture herbage is thin, and the soil is too leachy in character to give hope of satisfactory top-dressing results.

Merrimac coarse sand group. (Map symbol Z.) Such soils occur chiefly on the broad flat terrace lands in Windsor Locks, East Granby, Granby, Windsor, Suffield, Enfield, Wallingford, North Haven, North Canaan and Canaan, with a few smaller areas in other parts of the state. A medium to dark brown surface soil, of coarse sandy texture, with a yellow-brown coarse textured subsoil is formed over a substratum of stratified sand and fine gravel of light grayish-brown color.

The excessively sandy character of such soils makes moisture a serious limiting factor in dry seasons. In wet seasons soluble nutrients are leached out so rapidly that it is difficult to furnish the crop with adequate amounts of fertilizer. Tobacco under

shade is a successful crop in the Hartford County areas on the more favorable soils, while much of the land is overgrown with scrub oak, gray birch and pitch pine.

Merrimac sandy loam group. (Map symbol M.) These types occur on the level terrace lands of the Farmington and Connecticut valleys in Hartford County. They have medium brown surface soils of moderately sandy texture, with yellow-brown, slightly heavier subsoils developed over a well stratified sand and gravel substratum of grayish brown color composed chiefly of granitic material. The texture is highly favorable for the production of cigar leaf tobacco of excellent quality with the heavy fertilization usually practiced in this state. Early vegetables do well. Potatoes may suffer severely from dry seasons. Corn makes large yields, particularly on land with an accumulation of fertility from previous tobacco fertilization. Grass hay crops are short-lived, due to the sandiness of the soil. Alfalfa is a promising forage crop. The topography and character of the soil are less favorable for orchard fruits than on the upland soils of the state.

A high percentage of these soils is in cultivation.

Merrimac fine sandy loam. (Map symbol L.) These soils occur as terraces in the valleys of most of the important streams of the Eastern and Western Highlands, and as broader level areas along the borders of Long Island Sound in many of the shore towns. The surface soil is medium brown in color, of fine sandy loam and loam texture, with yellow-brown gravelly loam subsoil over a stratified gravel and coarse sand substratum of grayish brown color. They are favored for market gardening, trucking and potato growing, while the soil is sufficiently loamy to permit the growing of most general farm crops. Tobacco is the common crop in Hartford and Litchfield counties. Grass hay is less successful than on the upland soils. A considerable portion of these areas is occupied by cities, villages and shore resorts.

Hartford sandy loam group. (Map symbol R.) These soils occur as terraces along the smaller streams of the central lowland, adjacent to upland soils of the Wethersfield loam group. They are most extensively developed in New Haven County.

The surface soils are usually slightly gravelly, of dark reddish-brown color, with reddish-brown or reddish-yellow subsoils formed over well-stratified coarse sand and gravel composed chiefly of red sandstone and shale material. Under average conditions the Hartford soils are excellent for market-gardening, since they combine the qualities of "earliness," good drainage, and favorable topography, while a reasonably good moisture-holding capacity is favored by a somewhat higher humus and clay content than is usually found in sandy loam soils. Tobacco is grown over most of the areas of these soils that occur in the tobacco district.

Suffield clay loam group. (Map symbol F.) These soils are formed from deposits of clay laid down at the close of the ice age in certain areas in Hartford, Middlesex and New London Counties, chiefly in Suffield, Enfield, East Windsor, Windsor, Hartford, Berlin, Middletown, and North Haven. (The clays in the last three towns are of a reddish-chocolate, while the more northern deposits are of a drab color, with a corresponding difference in the soils derived from them.) They are light grayish-brown or light reddish-brown surface soils of silt loam or clay loam texture, with light grayish-brown, light olive-drab, or reddish-brown subsoils, developed over laminated clay of drab or reddish-chocolate color. The soils are entirely free from stony gravel or coarse sand.

The topography is level except along ravines where the streams have eroded through the clay beds. Drainage is often poor, except on the eroded slopes. They are difficult to till as compared to other soils of the state, and are most extensively used for hay and pasture. Certain areas where the texture of the surface soil is a very fine sandy loam are occasionally used for tobacco in the Hartford County section, but the heavier Suffield soils produce crops of poorer quality than the sandier soils of the same region.

Podunk silt loam group. (Map symbol A.) The most extensive area of these alluvial soils is on the flood plain of the Connecticut River, popularly known as the "meadows." A few other streams, notably the Farmington River, have flood plains of important extent, while many brooks and small rivers have narrow strips of "bottom-land" at intervals along their course. The surface soils are of a dark grayish-brown, gray-black or dark reddish-brown color, and of texture ranging from fine sand to silt loam. The subsoil is almost identical to the surface soil, usually becoming of a lighter gray somewhat mottled color with increasing depth. A deep substratum of light gray sand is frequently encountered.

The chief value of these soils is in the production of hay crops for long periods with little or no fertilizer treatment. More than 75 per cent of the Connecticut River meadows is in hay, chiefly of native grasses. The narrower bottom-lands of the smaller streams are generally used as pasture, with small areas in hay or corn. The higher-lying, least frequently flooded areas of the Connecticut and Farmington river bottoms are occasionally used for tobacco, corn and vegetable crops.

Whitman loam group. (Not represented on the Outline Map.) In practically all parts of the state there are many small areas of poorly drained upland soils, which occur in land depressions or on slopes that are kept water-logged through seepage. These scattered "spots" of soil, rarely more than a few rods wide, in the aggregate represent nearly one per cent of the total area of the state. Since they never group themselves in large blocks, no

attempt has been made to represent the Whitman soils on the Outline Map. The surface soils are very dark grayish-brown or gray-black in color, with subsoils showing noticeable mottlings of grayish-olive and reddish yellow-brown, as a result of poor drainage conditions. The substratum is usually an olive-gray colored coarse sandy clay in heavy sandy loam containing many rock fragments.

The Whitman soils always contain numerous boulders, unless they have been removed in the clearing of fields that are composed chiefly of better-drained soils. Patches of Whitman soils in such fields can be made quite productive for grass hay and corn if they are artificially drained. Larger Whitman areas have usually been relegated to pasture and woodland, the latter being composed of a strikingly large percentage of red maple.

Muck group. (Map symbol S.) Many land depressions, which were shallow ponds and small lakes for a considerable time after the close of the glacial period, have now become filled. Light gray fine sand and silt accumulated at the bottom of the water, which is now replaced by considerable depths of organic residues of sphagnum moss, sedges and forest debris in varying stages of decomposition.

If the material is thoroughly humified, partially mineralized, and of a nearly black color, it is called "muck." If less completely decomposed, and of a brown color, it is usually called "peat." Since most of such deposits in Connecticut are of the former character, such peat deposits as are known to exist in the state are mapped with the muck.

Both are strongly acid in character, and when drained for cultivation must be heavily limed and manured. Only a few small areas have been thus utilized for agriculture. A couple of generations ago much of the material was used as a soil amendment to add humus to soils that were excessively sandy or that "baked" badly in dry weather. Excessive labor costs have restricted this practice, and it seems probable that most of the muck and peat soils of the state will remain in woodland for some time to come, although they constitute a valuable potential resource for muck crop production, soil amendment and possible use as fuel.

Tidal marsh. (Map symbol K.) All the shore towns have tracts of these tidal marshes. They are never wooded, and are usually covered with sedge and wild grass vegetation. This growth is cut for "salt hay" and is largely used as bedding and packing material. The soil is composed of an admixture of fine silt with the humus remains of the above vegetation. It is impregnated with salt, and contains much lime from shell remains.

The agricultural reclamation of such areas is frequently practicable. It involves the construction of dikes (usually short in

proportion to the area reclaimed, since most of the marshes are fringed with natural sea walls in the form of coastal sand dunes), tide-gates, and a few large drainage ditches. The salt is leached out rapidly after permanent drainage of the marsh and most crops could safely be grown within three years. When economic conditions demand their utilization, many of these tidal marshes may prove a valuable agricultural asset, rather than continue to furnish a constant mosquito-control problem, as is now the case. In the meantime areas near population centers are being developed for factory and airport sites.

Holyoke stony loam group. (Map symbol T.) The trap rock ridges which are a conspicuous feature of the landscape in central Connecticut, while showing abrupt cliffs along their western face in most cases, are elsewhere covered to a rather shallow depth by these stony soils. The surface soil is a dark reddish-brown loam containing many angular fragments of trap rock. The subsoil is a reddish yellow-brown, very fine sandy loam, over either bedrock or a substratum of loose trap fragments usually more or less mixed with red sandstone and shale material.

Practically all such soils are in woodland, although a few of the smoother and less stony areas have been cleared for pasture.

Miscellaneous stony soils. (Map symbol X.) For the purposes of the Outline Map, all areas besides the Holyoke with a predominance of soils that are too stony for economic cultivation have been grouped together under this head. However, it is desirable that these be briefly described under several distinct headings, or sub-groups.

Sub-Group X-1. Stony Soils of Light Texture, with Perfect Surface Drainage and Rapid Underdrainage

Soils of this character form the highest percentage of both the Eastern and Western Highlands. They are developed on hilly or mountainous topography. In northern and eastern Litchfield County, northern Tolland County, eastern and southwestern New London County, southern Middlesex County, western New Haven County and northwestern Fairfield County the area is chiefly of this type, while considerable tracts of such land occur in almost every one of the highland towns.

The typical soil is the one described in detail later as the Gloucester Series, of which the Gloucester stony fine sandy loam is the most common type. The surface soil, in its virgin condition in the forest, consists of a thin layer of slowly decomposing leaf mold, resting upon a four or five inch layer of grayish yellow-brown fine sandy loam. When disturbed by the plow, this forms a six or seven inch horizon of medium brown fine sandy loam.

The subsoil, to the depth of about thirty inches, is a light yellow-brown fine sandy loam of friable consistency. Below this is to be found a coarse, rather loose and open mass of boulders, smaller rock fragments, sand and a relatively small percentage of silt and clay. The color of this material is predominantly gray. There are many boulders, from 20 to 50 per cent of the surface being occupied by stones more than eight inches in diameter. Small isolated fields have been partially cleared of stone by the herculean labors of the early settlers, who failed to realize that better land was to be found which could be brought under the plow with infinitely less exertion.

Other soils of similar characteristics are the stonier types of the Brookfield, Hinsdale, Maltby, Wilton, Coloma and Plymouth series. There is less than 10 per cent of improved land on such soils. These are located in small uneconomic units. Even when partially cleared of stone, the crop production is low, due to high acidity, general deficiency in available plant food material, excessive leachiness and poor drouth resistance.

From ten to 15 per cent of these soil areas are used for permanent pasture, practically all of which is of low grade. The edible native grasses, chiefly Rhode Island bent and redtop, make slow and irregular growth on account of adverse soil reaction, low fertility and severe dry weather damage, thus rapidly losing ground in competition with moss, cinquefoil, poverty grass, and dewberry vines. Bushy clumps of bayberry, sweetfern, juniper and sumac rapidly encroach on the open spaces. Gray birch or red cedar find excellent conditions for propagation, and unless heavily overgrazed or kept clear at great expense, the land rapidly reverts to these old field conditions, from which it is but a step to complete reversion to forest.

Eighty per cent or more of these soil areas is now occupied with some sort of woodland, much of which is of low grade. The chief reasons for the poor productivity of this land are as follows:

1. Being once cleared for tillage and pasture for considerable periods, the natural conditions of the forest soil have been destroyed. The fibrous organic matter of the original leaf mold has been broken up, and the soil reverting to woodland is in poor physical condition. The readily available food materials in this organic matter were dissipated, and the organic matter remaining in the soil is the residue that decomposes with difficulty.

2. The species predominating in unmanaged recently reverted stands are of undesirable type.

3. Areas have been repeatedly clear cut for firewood. The soil has been compacted through the beating action of rains and the breaking down of the normal crumb structure as a result of the reduced buffering effect of the leaf mold. Rapid decomposition

of organic matter and loss through excessive leaching occurs during the frequently recurring periods when the forest soil lies exposed.

4. Frequent and severe fires have consumed the natural humus conditions of the forest soil, and have destroyed the seeds furnishing reproduction for the best species.

Large areas of valuable forest also occur, when the removal of the virgin stand has been followed by wisely managed tree production, carefully guarded against fire and not subject to clear cutting for firewood as often as trees of from four to six inches in diameter are available. With adequate fire protection, the systematic weeding for firewood of the undesirable forest species, and a state taxation policy that encourages the landowner to permit the better species to grow to maturity, soils of this type will eventually be restored to their true conditions of productivity.

Sub-Group X-2. Stony Soils of Medium Texture, with Good Surface Drainage and Moderately Slow Underdrainage

Such soils constitute a considerable area of the highland regions of the state. They are most extensively developed in the northwestern part.

The typical soil is the Charlton stony loam. The surface soil in its virgin condition in the forest consists of a thin layer of well decomposed leaf mold resting upon a mellow, dark grayish-brown loam from three to four inches thick. Below this is a light grayish-brown fine sandy loam three or four inches in depth. The subsoil, to a depth of about 20 inches from the surface, is a grayish yellow-brown fine sandy loam of rather firm consistency. The substratum is a very compact grayish to yellowish olive-colored mass of sand and irregular rock fragments, with a considerable amount of silt and clay.

Other soils of similar characteristics except for minor color differences and of varied types of parent rock material are the stony types of the Dutchess, Hollis, Taugwank, Bernardston, Paxton, Woodbridge, Haddam and Litchfield series.

The percentage of cultivated land on such soils is also very small (less than 10 per cent), but their superior character for permanent pasture has resulted in an extensive use for this purpose estimated at from 20 to 30 per cent of the total area. Long periods of grazing without any attention to fertility maintenance has usually left such pastures in a low productive condition, except where used as night pasture with heavy barn feeding. There is a sparse growth of red top or Rhode Island Bent, some blue grass and white clover. Moss, cinquefoil, sumac and steeplebush are very prevalent. In northern Litchfield County the shrubby cinquefoil, *potentilla fructosa,* is a common pasture pest.

Pastures on these soils may be greatly improved by topdressing with superphosphate and lime and on more intensively grazed areas should also receive potash and nitrogen in the fertilizer treatment.

From 60 to 70 per cent of the soils of this group are in brush or woodland. More than 20 per cent of this is accounted for as areas previously kept clear for pasture. Recent changes in economic conditions have caused many former pasture fields to be permitted to grow up to brush.

In general, 50 per cent or more of the above soil group is in hardwood forest, usually in small form woodlot tracts. The productive conditions are somewhat better than those previously described for sub-group X-1. The soil has not been as sensitive to poor forest management, and perhaps in general there has not been the repeated clear cutting on the farm woodlot type of holdings as has been practiced on forest areas not in farms.

Sub-Group X-3. Rough Stony Land

This simple designation applies to a considerable area well distributed over the highland regions of the state, where the surface is so rough and broken in topography, or so completely strewn with large boulders that the topography and stoniness mask the effects of variations in the soil itself.

Practically all such land is in forest, and must remain so, except where the recreational and scenic possibilities warrant the clearing of small blocks for parks or country estates. Except where bedrock outcrops or lies within two feet of the surface, the fine earth among the loose stone is sufficiently deep and otherwise suitable for the maintenance of good natural stands of mixed hardwoods in the southern part of the state, and mixed hardwoods, hemlock and white pine in the northern part of the state. Where the areas have been severely burned, or clear cut repeatedly, the humus conditions of the soil have become unfavorable, resulting in poor growth and a predominance of practically worthless "weed" trees, such as gray birch, scrub oak and pitch pine.

A Key to the Soil Types of Connecticut

(The letter following the name of the soil type indicates the soil group to which it is assigned on the Outline Soil Map.)

a 1. Upland soils, derived from glacial till (unstratified rock debris).
 b 1. Well drained.
  c 1. With loose, coarse and very porous substratum (containing little or no clay) at from 28 to 36-inch depth.
   d 1. Derived from morainal deposits; usually with irregular topography.
    e 1. Rock material: mixed granite gneiss and schist. Light brown surface soil; brownish-yellow subsoil; grayish-yellow and very stony substratum, with many large, irregularly rounded boulders; distribution—in small, isolated areas, chiefly in extreme southeast portion of state.
     f 1. Moderately stony—**Plymouth loamy fine sand** (G).
     Plymouth fine sandy loam (G).
     f 2. Very stony—**Plymouth stony fine sand** (X).
     Plymouth stony fine sandy loam (X).
   d 2. Derived from glacial till overlying practically unweathered bedrock, usually at 10 to 25 feet depth; hilly to mountainous topography.
    e 1. Rock material: grayish-colored granite-gneiss. Medium brown surface soil; yellow brown subsoil; brownish-gray to gray, coarse and stony substratum; distribution—very extensive over both Eastern and Western Highlands.
     f 1. Moderately stony—**Gloucester fine sandy loam** (G).
     Gloucester loam (G).
     f 2. Very stony—**Gloucester stony fine sandy loam** (X).
     Gloucester stony loam (X).
     f 3. Very stony; similar to Gloucester, but showing noticeable grayness in the mineral soil underlying the forest humus when observed under woodland conditions (podsolized).
     —**Hermon stony fine sandy loam.**
   d 3. Derived from glacial till overlying partially weathered bedrock at variable depth, usually less than 10 feet, topography hilly to mountainous.
    e 1. Rock material: light gray quartzite or quartz-schist. Light brown surface soil; light brownish-yellow subsoil; light gray substratum with much fine sand mixed with broken quartzite or quartz-schist rock fragments; distribution—chiefly in extreme eastern portion of state, in Putnam, Killingly and Plainfield.
     f 1. Moderately stony—**Coloma loamy fine sand** (G).
     Coloma fine sandy loam (G).
     f 2. Very stony—**Coloma stony loamy fine sand** (X).
     Coloma stony fine sandy loam (X).
    e 2. Rock material; mica schist. Brown surface soil, with slight reddish coat; reddish yellow-brown subsoil; light yellowish brown substratum consisting chiefly of disintegrating mica-schist; distribution—extensive in many parts of Eastern and Western Highlands especially on stony, non-agricultural areas.

f 1. Moderately stony—**Brookfield fine sandy loam (G).**
Brookfield loam (G).
f 2. Very stony—**Brookfield stony fine sandy loam (X).**
Brookfield stony loam (X).
e 3. Rock material: dark gray granite gneiss, usually with large crystals; medium brown surface soils; yellow-brown subsoil with slight reddish cast; light yellowish-brown to grayish-brown substratum with many slightly discolored, sharply angular rock fragments; not micaceous; distribution — extensive in Eastern Highland, especially west of Connecticut River.
f 1. Moderately stony—**Hinsdale fine sandy loam (G).**
Hinsdale loam (G).
f 2. Very stony—**Hinsdale stony fine sandy loam (X).**
Hinsdale stony loam (X).
e 4. Rock material: dioritic schist with high percentage of hornblende. Dark brown surface soil with slight reddish cast; reddish yellow-brown subsoil; grayish-brown substratum with many nearly black rock fragments; only slightly micaceous; distribution—a few important areas in southern Fairfield County, chiefly in Wilton, Weston and Westport, local in Brookfield and New Milford.
f 1. Slightly to moderately stony—
Wilton fine sandy loam (G).
Wilton loam (G).
f 2. Very stony—**Wilton fine sandy loam (X).**
Wilton stony loam (X).
e 5. Rock material: greenish-gray chlorite schist. Medium to dark brown surface soil; reddish-yellow subsoil, noticeably more sticky when wet than surface soil; light gray to pinkish-gray substratum with much fine sand mixed with disintegrating chlorite rock; distribution—Woodbridge, West Haven and Orange, chiefly on stony, non-agricultural areas.
f 1. Moderately stony—**Maltby fine sandy loam (I).**
Maltby very fine sandy loam (I).
f 2. Very stony—**Maltby stony fine sandy loam (X).**
Maltby stony loam (X).
e 6. Rock material: bluish-gray phyllite or slate, dark grayish-brown surface soil; yellow-brown to olive-drab subsoil; bluish-gray substratum consisting chiefly of a soft mass of disintegrating phyllite or slate; distribution—Bethany, Woodbridge, Orange, Milford, and Stratford.
f 1. Slightly to moderately stony—**Hollis loam (I).**
Hollis silt loam (I).
Hollis shaly loam (I).
f 2. Very stony—**Hollis stony loam (X).**
e 7. Rock material: shaly schists. Medium gray-brown surface soil; greenish-yellow to yellowish-olive subsoil; yellowish olive substratum, firm and composed of disintegrating shale fragments; distribution—extreme northwestern part of state in Salisbury and Sharon.
f 1. Slightly to moderately stony—
Dutchess loam (D).
Dutchess silt loam (D).
Dutchess shaly loam (D).

f 2. Very stony—**Dutchess stony loam** (X).

e 8. Rock material: impure limestones and shaly dark olive-brown surface soil. Greenish-yellow subsoil; olive-drab substratum with disintegrating schist and limestone fragments; often somewhat micaceous; distribution—Sharon and New Milford.

f 1. Slightly to moderately stony—
Pittsfield fine sandy loam (D).

f 2. Very stony—**Pittsfield stony fine sandy loam** (X).

e 9. Rock material: principally limestone or marble. Light to medium brown surface soil; yellow to reddish-yellow brown subsoil; light gray to nearly white substratum with disintegrated limestone or marble fragments; distribution—Shawn, upper Housatonic Valley and in vicinity of Danbury.

f 1. Slightly to moderately stony—
Dover fine sandy loam (D).

f 2. Very stony—**Dover stony fine sandy loam** (X).

d 4. Derived from glacial till of variable depth, usually very shallow, overlying practically unweathered bedrock; very rugged topography as a rule; commonly adjacent to steep cliffs without soil covering.

e 1. Rock material; chiefly basaltic or dioritic "trap." Dark chestnut-brown to reddish-brown surface soil; reddish yellow-brown subsoil; grayish to yellowish-brown substratum usually composed chiefly of slightly weathered angular fragments of "trap" rock. Distribution—coincident with the "trap" ridges which rise from the central lowland of Connecticut. The areas are usually of the very stony type.

f 1. Moderately stony—
Holyoke very fine sandy loam (T).
Holyoke loam (T).

f 2. Very stony—**Holyoke stony loam** (T).

e 2. Rock material—massive, coarse, conglomerate sandstone of pinkish-gray color; medium brown surface soil; reddish yellow-brown subsoil; brownish gray coarse gravelly substratum (gravel formed from disintegration of the conglomerate rock); distribution—local occurrence in southern Middletown and northern Durham.

f 1. Moderately stony—**Middletown loam** (W).

f 2. Very stony—**Middletown stony loam** (X).

c 2. With dense, compact glacial till substratum containing a moderate amount of clay (so-called "hardpan").

d 1. Derived from deep glacial till of drumlin or drumloid character; topography well rounded hills of uniform slope; soil and subsoil extend to compact substratum more than 24 inches below surface.

e 1. Rock material: grayish-colored granite gneiss. Grayish-brown surface soil; grayish yellow-brown subsoil; olive-drab substratum, becoming very compact at 28 to 30 inches below surface; distribution—very common occurrence in both Eastern and Western Highlands of the state, particularly in southern portion of Western Highland on the smoother ridge tops.

f 1. Slightly stony—**Woodbridge fine sandy loam** (C).
Woodbridge loam (C).

f 2. Moderately to very stony—
Woodbridge stony fine sandy loam (X).
Woodbridge stony loam (X).

f 3. Moderately to very stony. Similar to Gloucester but showing definite grayness in the mineral soil underlying the forest humus when observed under woodland conditions (podsolized)—
Becket stony loam (X).

e 2. Rock material: mixed granite gneiss and schist. Grayish-brown to dark grayish-brown surface soil; grayish yellow-brown subsoils; yellowish-olive to olive-drab substratum, becoming very compact at 24 to 28 inches below surface; distribution—very common occurrence in Western Highland and particularly in the northern portion of the Eastern Highland, on the more distinctly drumlin type of topography.

f 1. Slightly stony—**Charlton fine sandy loam** (C).
Charlton loam (C).

f 2. Moderately to very stony—
Charlton stony fine sandy loam (X).
Charlton loam (X).

e 3. Rock material: quartz-schist, quartzite or granite gneiss containing much quartz. Dark grayish-brown surface soil; grayish yellow-brown subsoil becoming slightly mottled at 18 to 24 inches; gray to olive-gray substratum of very compact character at 28 to 30 inches below surface; distribution—chiefly in southern Windham County, on the flatter ridge tops.

f 1. Slightly to moderately stony—
Taugwank fine sandy loam (C).
Taugwank loam (C).

f 2. Very stony—**Taugwank stony loam** (X).

e 4. Rock material: dark gray granite gneiss, containing many crystals of biotite and hornblende. Medium brown surface soil; light brown subsoils; light brown to grayish-brown substratum, occasionally with a slight "pinkish" cast, becoming very compact at 28 to 30 inches below surface; distribution—principally confined to that portion of Eastern Highland that lies in Middlesex and New Haven Counties, on smoothly rolling ridges adjacent to rougher areas of soils of *Hinsdale* types.

f 1. Slightly to moderately stony—
Haddam fine sandy loam (C).
Haddam loam (C).

f 2. Very stony—**Haddam stony fine sandy loam** (X).
Haddam stony loam (X).

e 5. Rock material: bluish gray phyllite or slate. Dark olive-brown surface soil; dark olive-drab subsoil; "bluish" olive substratum consisting of a compact mesa of disintegrated chips of phyllite or slate at 24 to 28 inches below surface; distribution—confined to Bethany, Woodbridge, Orange and Milford on drumlin hills adjacent to areas of *Hollis* soils.

f 1. Slightly to moderately stony—
Bernardston loam (I).
Bernardston silt loam (I).

e 6. Rock material: impure limestones and shale. Grayish brown surface soil; yellow-brown to greenish-yellow subsoil; olive-drab substratum, compact at 24 to 30 inches from surface, and containing some limestone fragments; distribution—Sharon and New Milford.

f 1. Slightly to moderately stony—
Lenox fine sandy loam (D).
Lenox loam (D).

f 2. Very stony—**Lenox stony fine sandy loam** (X).
Lenox stony loam (X).

e 7. Rock material: reddish-brown to reddish-gray coarse textured sandstone. Medium-brown surface soil; slightly reddish yellow-brown subsoil; light reddish-brown to reddish-gray substratum consisting of a compact, sandy mass of disintegrating sandstone fragments; distribution—very common on the hilly portion of the central lowland.

f 1. Slightly to moderately stony—
Cheshire sandy loam (W).
Cheshire fine sandy loam (W).
Cheshire loam (W).

f 2. Very stony—**Cheshire stony fine sandy loam** (X).
Cheshire stony loam (X).

e 8. Rock material: brownish-red fine textured sandstone or shale. Reddish-brown surface soil; light reddish-brown subsoil; brownish-red substratum consisting of a very compact mass of disintegrating sandstone and shale fragments; distribution—very common on the hilly portion of the Central Lowland.

f 1. Slightly to moderately stony—
Wethersfield fine sandy loam (W).
Wethersfield loam (W).
Wethersfield clay loam (W).

f 2. Very stony—**Wethersfield stony loam** (X).

d 2. Derived from very deep glacial till of drumlin character; topography—elongated hills of distinctly rounded surface; soil and subsoil extend downward to very compact substratum at less than 24 inches below surface.

e 1. Rock material: schists, gneiss and slates. Olive-brown surface soil; yellowish-olive to olive-drab subsoil; olive-drab substratum of very compact glacial till at from 16 to 20 inches below surface. Good drainage as a result of sloping land surface in spite of slowness of underdrainage; distribution—in many parts of the Eastern and Western Highlands, on the crests of the more perfectly shaped drumlin hills.

f 1. Slightly to moderately stony—
Paxton fine sandy loam (C).
Paxton loam (C).

e 2. Rock material: chiefly of schistose character. Dark grayish-brown surface soil; yellowish-olive subsoils, usually heavier in texture than surface soil; olive-drab to grayish-olive substratum of very compact glacial till at from 18 to 24 inches below surface; drainage slow in early spring, due to moderately level topography and compact substratum at shallow depth; distribution—on the broad, flatter-crested drumlin ridges in central Litchfield County.

f 1. Slightly to moderately stony—
Litchfield fine sandy loam (C).
Litchfield loam (C).

f 2. Very stony—**Litchfield stony loam** (X).

b 2. Imperfectly drained upland soils.

c 1. With temporarily high water table in spring due to excessive seepage from adjacent higher areas; drainage usually good in late summer and early fall.

d 1. Derived from glacial till of relatively shallow depth (less than 15 feet); topography—lower slopes and bench lands; usually at the head or along margins of hillside ravines.

e 1. Rock material: mixed gneiss and schist. Dark grayish-brown surface soil; yellow-brown subsoil, substratum-mottled gray and rusty yellow grading to light gray at lower depths, and of coarse and stony character; distribution—very general in Eastern and Western Highland.

f 1. Moderately stony—**Peru fine sandy loam** (G).
Peru loam (G).

f 2. Very stony—**Peru stony fine sandy loam** (X).
Peru stony loam (X).

d 2. Derived from deep glacial till of compact character containtaining a considerable amount of clay; topography—level or nearly level portions of broad-crested drumlins.

e 1. Rock material: schist and gneiss, with schist predominant. Very dark brown to gray-black surface soil; olive-drab and moderately compact subsoil; substratum mottled gray and rusty yellow becoming grayish-olive in color at greater depths, very compact; with few stones or boulders, except on surface; distribution—occasional in areas where Charlton and Litchfield soils occupy most of the adjacent area, as in towns of Lebanon, Pomfret, Woodstock and in central Litchfield County.

f 1. Slightly to moderately stony—**Sutton loam** (C).

f 2. Very stony—**Sutton stony loam** (X).

c 2. With high water table during most of the year.

d 1. Derived from glacial till of relatively shallow depth (less than 15 feet); topography—lower slopes, at heads and along hillside ravines, in wider areas along small brooks that do not overflow their banks to form alluvial deposits, and other poorly drained depressions not occupied by deep organic accumulations.

e 1. Rock material: mixed granite gneiss, schist, and other non-calcareous, igneous, or metamorphic rocks. Gray-black surface soil; mottled gray and rusty yellow subsoil; light gray to bluish-gray coarse, stony substratum, occasionally with sandy clay, usually water-logged at all times; distribution—general in all parts of the Eastern and Western Highland.

f 1. Moderately stony—**Whitman fine sandy loam** (G, C).
Whitman loam (G, C).
Whitman sandy clay loam (G, C).

f 2. Very stony—**Whitman stony loam** (X).

e 2. Rock material: mixed schist and limestone. Gray-black to black mucky surface soil; gray or grayish-olive-yellow mottled subsoils; light gray to bluish-gray calcareous substratum of compact character with few stone or boulders; distribution—a few small areas in Sharon; the upper Housatonic Valley, New Milford and Danbury.

f 1. Slightly to moderately stony—**Lyons loam** (D).

e 3. Rock material: reddish-brown sandstones and shales. Very dark brown surface soil, with a slight reddish cast; mottled light-reddish brown and rusty yellow subsoil; grayish red-brown to pinkish-gray substratum, with sandstone or shale fragments; distribution—in central Connecticut adjacent to *Wethersfield* and *Cheshire* types.

f 1. Slightly to moderately stony—

Whitfield loam (W).
Whitfield clay loam (W).

a 2. Valley soils, developed over stratified glacial rock debris (sand, gravel and clay).

b 1. Well drained.

c 1. With loose, coarse, gravelly and sandy substratum at from 24 to 36 inches depth.

d 1. Derived from kames, eskers and similar deltal deposits of irregular topography.

e 1. Rock material: mixed non-calcareous metamorphic rocks (schists and gneiss). Medium brown surface soil; yellow brown subsoil; brownish gray substratum of coarse sand and gravel; distribution—very general in both the Eastern and Western Highlands, where they form irregular, frequently interrupted belts along the lower slopes of the hills that have a mantle of unstratified glacial debris (till)—most extensively developed in the Quinnebaug Valley.

f 1. Not excessively sandy or gravelly—

Hinckley fine sandy loam (H).
Hinckley sandy loam (H).
Hinckley gravelly fine sandy loam (H).

f 2. Excessively sandy or gravelly—

Hinckley gravelly sandy loam (H).
Hinckley loamy sand (H).
Hinckley gravel loam (H).

e 2. Rock material: schists and phyllite slates. Medium brown surface soil; reddish yellow-brown subsoil; light yellowish-brown to olive-drab substratum chiefly composed of rounded chips of slate and schist; distribution—in Woodbridge, Orange and Milford, adjacent to areas of *Hollis* soils.

f 1. Not excessively sandy or gravelly—

Hancock fine sandy loam (H).
Hancock very fine sandy loam (H).
Hancock loam (H).

f 2. Excessively gravelly—**Hancock gravel loam.**

e 3. Rock material: mixed gneiss, schist and limestone or marble. Brown surface soil; yellow-brown or reddish yellow-brown subsoil; gray sand and gravel substratum, frequently partially cemented together with calcareous material below a depth of four or five feet; distribution—in upper Housatonic Valley and in Danbury, adjacent to areas of *Dover* soils.

f 1. Not excessively sandy or gravelly—
Rodman fine sandy loam (H).
Rodman sandy loam (H).

f 2. Excessively sandy or gravelly—
Rodman loamy sand (H).
Rodman gravel loam (H).

e 4. Rock material—brownish-red sandstones and shales. Medium brown surface soil with slight reddish cast; reddish yellow-brown subsoil; brownish-red substratum of sand and gravel; distribution—common occurrence on areas of irregular hummocky topography in central lowland of Connecticut, adjacent to areas of Cheshire and Wethersfield soils.

f 1. Not excessively sandy or gravelly—
Manchester sandy loam (N).
Manchester fine sandy loam (N).
Manchester gravelly fine sandy loam (N).
Manchester loam (N).

f 2. Excessively sandy or gravelly—
Manchester gravel loam (N).
Manchester loamy sand (N).

d 2. Derived from level or nearly level terraces of sand and gravel deposited at the close of the glacial epoch.

e 1. Rock material: mixed schists and gneiss. Medium to dark brown surface soil; yellow-brown or brownish-yellow subsoil; gray to brownish-gray substratum of well-stratified sand or gravel; distribution—most extensive on the wider terrace lands in Hartford County, and as narrower terraces in many valleys in all parts of the state.

f 1. Not excessively sandy—
Merrimac sandy loam (M).
Merrimac fine sandy loam (L).
Merrimac loam (L).
Merrimac gravelly fine sandy loam (L).

f 2. Excessively sandy—
Merrimac loamy fine sand (M).
Merrimac loamy sand (M).
Merrimac coarse sand (Z).

e 2. Rock material: slates and phyllite. Medium brown surface soil; reddish yellow-brown subsoil; olive-drab or bluish-olive substratum with many rounded chips of phyllite or slate; distribution—in Orange and Milford, adjacent to areas of Hollis soils.

f 1. **Fairlea fine sandy loam** (L).
Fairlea very fine sandy loam (L).
Fairlea gravelly very fine sandy loam (L).

e 3. Rock material: shales and shaly schists. Olive-brown surface soil; yellowish-olive subsoil; grayish-olive substratum of sand and gravel, containing many rounded fragments of shale and schist; distribution—upper Housatonic Valley.

f 1. **Sheffield fine sandy loam** (L).
Sheffield loam (L).

e 4. Rock material: mixed schist, gneiss and limestone. Medium brown surface soil; yellow-brown subsoil; grayish sand and gravel substratum containing sufficient limestone material to show effervescence with hydrochloric acid; distribution—a few small areas on terraces of the Housatonic Valley, adjacent to areas of *Dover* soils.

f 1. Not excessively sandy or gravelly—
Palmyra fine sandy loam (L).
Palmyra gravelly fine sandy loam (L).

f 2. Excessively gravelly—**Palmyra gravel loam.**

e 5. Rock material: brownish red sandstones and shales. Dark brown surface soil, with slight reddish cast; reddish yellow-brown subsoil; grayish-red substratum of sand and gravel, chiefly of sandstone and shale material; distribution—narrow terraces along most streams of the central lowland, excepting the Connecticut River terraces, which are chiefly *Merrimac* soils.

f 1. Not excessively sandy or gravelly—
Hartford sandy loam (R).
Hartford fine sandy loam (R).
Hartford loam (R).
Hartford gravelly fine sandy loam (R).

f 2. Excessively gravelly—**Hartford gravel loam** (R).

c 1. With fine or very fine sand substratum at 24 to 36 inches depth.

d 1. Occurring on level terraces, forming the lowest terrace of the Connecticut River, which lies about 60 feet above sea level.

e 1. Rock material: gneiss and schists. Medium grayish-brown surface soil; brownish-yellow subsoil; gray to olive-gray substratum of fine sand, with little or no gravel; distribution—just above the Connecticut River flood plain in the towns of Suffield and Enfield.

f 1. Not excessively sandy or gravelly—
Agawam fine sandy loam (M).
Agawam very fine sandy loam (M).

d 2. Occurring on rolling topography; fine or very fine sand substratum underlain with reddish-colored sand, gravel or stony till at from three and one-half to five feet depth.

e 1. Rock material: finely divided crystalline fragments deposited by ancient wind action as a thin mantle (three to five feet deep) overlying previously deposited stratified and unstratified glacial debris that is chiefly of red sandstone and shale material. Light brown surface soil with no gravel or coarse sand; grayish yellow-brown subsoil; olive gray fine sand or very fine sand substratum, which changes abruptly at three and one-half to five feet depth to coarser sand and gravel or stony glacial till of red brown color; distribution—in Hartford County, chiefly in towns of Enfield, East Windsor, South Windsor, East Hartford and Suffield.

f 1. Not excessively sandy or gravelly—
Enfield fine sandy loam (E).
Enfield very fine sandy loam (E).

d 3. Occurring on level topography; fine or very fine sand substratum underlain with stratified clay and silt at three and one-half to five feet depth.

e 1. Rock material: finely crystalline fragments deposited by ancient wind action as a thin mantle three and one-half to five feet deep overlying previously deposited stratified clay and silt. Light grayish-brown surface soil, free from gravel or coarse sand; grayish yellow-brown to yellowish-olive subsoil; olive-gray and rusty yellow mottled very fine sand substratum which changes abruptly to clay at from three and one-half to five feet depth; distribution—Hartford County, principally in East Windsor and Enfield.

f 1. Not excessively sandy or gravelly—
Melrose fine sandy loam (E).
Melrose very fine sandy loam (E).

d 4. Occurring on level topography or as eroded terrace slopes; heavy silty clay at 20 to 24 inches depth.

e 1. Parent material: stratified clay and silt of olive-drab color, originally deposited on the bed of extinct lakes existing at the close of the glacial epoch. Grayish-drab surface soil; olive-drab subsoil; olive-drab substratum of clay and silt; distribution—Hartford County, chiefly in Hartford, Windsor, Windsor Locks, Suffield, Enfield, East Windsor and South Windsor.

f 1. Not excessively sandy or gravelly—
Suffield very fine sandy loam (F).
Suffield silt loam (F).
Suffield clay loam (F).

e 2. Parent material: red brown stratified clay and silt. Grayish-brown surface soil; yellowish red-brown subsoil; red-brown substratum of clay and silt; distribution—chiefly in Berlin, Middletown and North Haven.

f 1. **Berlin silt loam** (F).
Berlin clay loam (F).

b 2. Imperfectly drained.

c 1. With coarse gravelly and sandy substratum at 24 to 36 inches depth.

d 1. Occurring on level terrace lands.

e 1. Parent material: sand and gravel of granite gneiss and schist rock. Very dark grayish-brown to gray-black surface soil; grayish-yellow subsoil, somewhat mottled (gray and rusty yellow) and partially cemented together as "iron-hardpan" at 20 to 24 inches depth; mottled gray—rusty yellow substratum of sand and gravel, water-logged during most of the year; distribution—occasional poorly drained spots on terraces of *Merrimac* soils.

f 1. **Scarbro sandy loam** (M).
Scarbro loam (L).

e. 2. Parent material: sand and gravel of red-brown sandstone and shale rock. Dark grayish-brown surface soil; reddish-yellow brown subsoil, grading at 15 to 18 inches to mottled reddish-gray and rusty-brown; reddish-gray substratum of sand and gravel, chiefly derived from reddish-colored sandstone and shale rock; water-logged during most of the year; distribution—occasional poorly drained terrace lands adjacent to *Wethersfield* and *Cheshire* soils in the central lowland.

f 1. **Ellington loam** (R).

c 2. With heavy clay substratum at 20 to 24 inches depth.

d 1. Occurring in poorly drained low-lying areas underlain with clay.

e 1. Parent material: stratified clay and silt of olive-drab color. Gray black to dark grayish-brown surface soil, heavy, mottled olive-gray and rust-brown subsoil; slightly mottled olive-drab clay substratum; distribution—occasional poorly drained areas adjacent to *Suffield* soils in Hartford County.

f 1. **Scantic loam** (F).
Scantic clay loam (F).

a 3. Alluvial soils—periodically overflowed by flood waters of existing streams.

b 1. Well drained.

c 1. With fine sand substratum at 24 to 30 inches depth.

d 1. Occurring on infrequently flooded portions of the flood plains.

e 1. Parent material: river-deposited fine sand. Medium brown surface soil; yellow-brown subsoil; brownish-gray substratum of fine sand; distribution—on the higher portions of the Connecticut River flood plain, and along a few other large streams of the state.

f 1. Not excessively sandy—
Ondowa sandy loam (A).
Ondowa fine sandy loam (A).
Ondowa silt loam (A).

f 2. Excessively sandy—**Ondowa loamy fine sand** (A).

b 2. Imperfectly drained over most of the area (excessively sandy soils sometimes with very rapid drainage).

c 1. With no well defined color differences between soil, subsoil and substratum; substratum at 36 to 40 inches depth, usually composed of fine sand and silt.

d 1. Occurring on frequently flooded portions of flood plains.

e 1. Parent material: stream deposits washed down from areas of granite gneiss and schist. Dark grayish-brown surface soil; grayish-brown subsoil; brownish-gray to grayish-brown substratum of variable character, ranging from silt loam to loamy sand; distribution—most extensive areas lie on the main portion of the Connecticut River flood plain, smaller areas include most of the "bottomland" along other streams of the state.

f 1. Not excessively sandy—
Podunk silty clay loam (A).
Podunk silt loam (A).
Podunk very fine sandy loam (A).
Podunk fine sandy loam (A).
Podunk sandy loam (A).

f 2. Excessively sandy—**Podunk loamy fine sand** (A).
Podunk loamy sand (A).
Podunk sand (A).

e 2. Parent material: stream deposits washed down from areas of red-brown sandstones and shales. Very dark brown surface soil with slight reddish cast; red-brown subsoil; brownish-red substratum of clay, sand or silt; distribution—as narrow "bottomlands" along a number of small streams in the central lowland of the state.

f 1. Not excessively sandy—
Middlefield clay loam (A).
Middlefield loam (A).
Middlefield fine sandy loam (A).

a 4. Organic soils.
b 1. Poorly drained.
c 1. Inland, fresh-water deposits.
d 1. Occurring in land depressions that receive no alluvial deposits.
e 1. Organic material chiefly composed of forest leaves, shrubby and herbaceous growth. Humus soil black, mellow, well disintegrated, and extending to a mineral substratum of bluish-gray fine sand at depth ranging from less than two feet to 40 feet or more; distribution—in individual areas from less than acre up to about 500 acres distributed over practically every town of the state.
f 1. Mineral substratum less than three feet below surface—**Shallow muck** (S).
f 2. Mineral substratum three feet or more below surface—**Muck** (S).
e 2. Humus soil of brown color, fibrous, composed chiefly of residues from rushes, sedges and sphagnum moss; mineral substratum usually 25 feet or more below surface except at swamp margins; distribution—occasional small areas, chiefly in the Eastern and Western Highlands.
f 1. **Peat** (S).
c 2. Coastal, salt water deposits.
d 1. Occurring as flat areas, periodically flooded by tidal waters.
e 1. Organic material chiefly derived from "salt marsh" vegetation (sedges predominant), surface layer of grayish-brown fibrous residues; lower layers—brownish-gray to bluish-gray, brown-mottled, silty or sandy clay, high in organic matter, containing a high salt concentration, with some shell-fish remains; distribution—along Long Island Sound and its tidal bays and inlets.
f 1. **Tidal marsh** (K).

a 5. Miscellaneous land areas with no definite soil characteristics.
b 1. Surface almost completely paved with large boulders but with a fair depth of soil lying under and between the rocks—
Rough stony land (X).
b 2. Area practically bare, with bedrock exposed—**Rock outcrop** (X).
b 3. Clean, loose sand fringing exposed shores of Long Island Sound, which are swept by waves, tides and wind—**Coastal beach** (K).
b 4. Sand and gravel areas along rapidly flowing streams which are washed clean of all fine earth material by strong channel currents during flood periods—**Riverwash.**
b 5. Areas built up from an original lower level by the dumping of refuse and excavation earth and stone—**Made land.**
b 6. Areas where soil has been removed, exposing the substratum of sand and gravel for use in building and road construction—**Gravel bank.**

PART II

SOIL AND LAND COVER STUDIES

Fifteen areas typical of soil conditions to be found in various parts of the state and indicated on Figure 62, have been intensively surveyed. Maps were prepared showing all soil types and the distribution of crops, pasture, forest and other land use upon these soils.

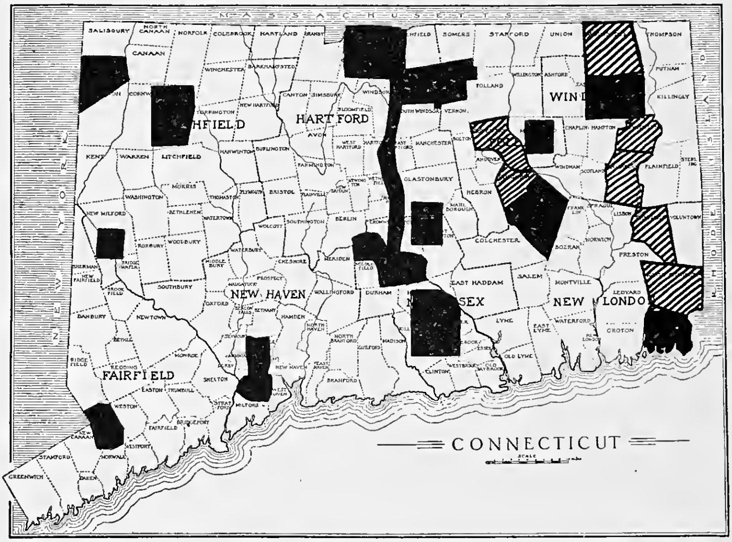

FIGURE 62. Areas over which the soils have been studied in detail. Solid block, soil and land cover surveys for the entire area; shaded, surveys of selected farms within the towns.

In 1928 and 1929, these surveys were supplemented by the results of detailed mapping of the distribution of soils on 190 dairy farms in the towns of Woodstock, Griswold, Coventry, Brooklyn, Columbia, Stonington, North Stonington and Canterbury. These farms are being carefully studied by the Economics Department of the Storrs station, which has also made economic surveys of the Lebanon, Suffield and East Windsor areas, for which soil and land cover maps were prepared.

Complete data as to the details of the distribution of land cover on the soils of these areas is somewhat too voluminous for presen-

tation in this bulletin, but it is hoped that they may be published in their entirety at a later date.

Important soils represented in two or more different areas present a somewhat different picture of land cover, depending upon the relative occurrence of other more or less favorable soils as well as other frequently explicable factors. An example is indicated in comparisons of the results of the land cover tabulation for the less-stony phases of the Gloucester and Charlton soils in the Lebanon, Stonington, Pomfret, Goshen and Wilton areas.

TABLE III. LAND COVER DISTRIBUTION ON GLOUCESTER AND CHARLTON SOILS IN SELECTED AREAS.

Area and soil	Percentages: Tilled land and mowing	Open pasture	Brush and "old field"	Hardwood forest
Lebanon-Gloucester	30.9	19.7	5.5[1]	43.9
Charlton	50.0	26.7	2.8[1]	20.5
Pomfret-Gloucester	30.9	5.0	28.9	35.2
Charlton	54.8	6.76	15.3	23.2
Goshen-Gloucester	48.5	28.9	6.5	16.0
Charlton	56.5	16.5	10.9	16.1
Wilton-Gloucester	43.9	8.7	27.0	20.4
Charlton	56.1	15.9	18.6	9.4
Stonington-Gloucester	57.6	5.0	23.0	14.4
Charlton	62.5	5.8	24.2	7.5

In every area Charlton soils show a higher percentage of tilled land and mowing than Gloucester, yet in towns such as Stonington, with an abnormally large area of extremely stony soils, an unusually high percentage of the small areas of the less-stony phases is in crop production.

The effect of other factors than soil is observed in the land cover distribution in the Goshen area, with respect to open pasture and brush lands. In this town, pastures are quite commonly infested with shrubby cinquefoil (*Potentilla fructosa*) which is much more prevalent on the Charlton pasture areas than on the "drier" Gloucester soil. Summers are cooler and as a consequence Gloucester pastures suffer less severely from dry seasons in Goshen than they might in Stonington. Therefore an unusually high percentage of open pasture is indicated for the Goshen Gloucester soils while the Charlton soils are there so difficult to keep clear of the shrubby cinquefoil that an abnormal portion of the pastures is grown up to brush land or abandoned to gray birches.

In spite of the failure to obtain strictly comparable results in all cases, a tabulation of the data by important soil groups for all of the areas reveals certain important adjustments of land use to the character of the soil.

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[1] "Old field," or gray birch areas, were mapped with the woodland in the Lebanon area.

As would be expected, the more adverse stony and poorly drained soils have largely gone out of cultivation. This is shown by the following table:

Table IV. Land Cover on Stony and Poorly Drained Soils.

Soil types	Percentages: Tilled and mowed	Open pasture	Brush land "old field"	Forest
Holyoke stony soils	1	2	1	96
Brookfield Hinsdale stony soils	3	5	5	87
Gloucester stony soils	7	11	16	66
Charlton stony soils	12	21	23	56
Whitman loam (poorly drained)	18	18	20	56
Muck	11	10	23	56

Other soils, with adverse factors depending upon texture, water-holding capacity and general fertility exhibit marked differences in land cover distribution.

Table V. Land Cover on Important Agricultural Soils.

Soil types	Percentages: Tilled and mowing	Open pasture	Brush and "old field"	Forest
Enfield v. f. s. l.	70	3	3	24
Merrimac sandy loam	61	8	3	28
Wethersfield f. s. l. and related soils	60	8	5	27
Merrimac fine sandy loam	58	11	8	23
Charlton loam and related soils	56	13	13	28
Suffield silt and clay loam	53	26	3	18
Merrimac coarse sand	44	0.25	8.75	47
Gloucester f. s. l.	36	17	10	37
Podunk loam[1]	34	21	8	37
Hinckley gravelly sandy loam	33	11	25	31

In the tobacco district, two areas have shown that this crop is largely confined to certain soil types. The selection of these soils for tobacco is shown in Table VI.

Table VI. Tobacco on Soils of the Suffield and East Windsor Areas.

Soil type	Percentage of cultivated area in tobacco
Merrimac sandy loam	52
Merrimac coarse sand	45 (shade)
Enfield v. f. s. l.	40
Manchester gravelly fine s. l.	33
Wethersfield and Cheshire f. s. l. and loam	26
Podunk f. s. l. and loam	20
Suffield silt and clay loam	12

A study of the distribution of commercial apple orchards has shown that these are confined largely to the Charlton and Wethers-

[1] Not including Connecticut River "meadows," which is almost entirely used for native grass hay.

field groups. It is significant that in spite of the large areas of the Gloucester and Merrimac groups of soil, practically no commercial orchards are located upon them.

General Development of Productive Farm Enterprises on Important Soil Types

Dairying. This enterprise, as now being conducted, should prove most successful on lands well suited to the production of silage, hay crops, and pasture. The Charlton, Dover, Wethersfield and Suffield groups of soils most nearly meet these requirements. In spite of the adverse economic conditions that now place Gloucester soils under a serious handicap, dairying still remains the chief enterprise on most of that group. Special local markets have enabled many farms lying chiefly on the adverse sandy Merrimac types to continue to follow dairying as a major pursuit.

Orcharding. As already mentioned, commercial orchards reach their best development on the Wethersfield and Charlton soils. Small home orchards may prove successful on the Gloucester soils, but are generally less satisfactory on the Merrimac, Hartford and Hinckley series.

Small fruits. The chief culture of small fruits is on the Manchester, Hartford and Wethersfield series, and to a slighter extent on the Merrimac and Gloucester series.

Vegetable crops. The sections of most intensive commercial vegetable production are on the Merrimac sandy loam and fine sandy loam, Hartford, Wethersfield and Manchester series. In the vicinity of cities and towns where these soil types are not available, the Gloucester and the less-gravelly phases of Hinckley soils are brought into use. The heavier Charlton and Suffield soils are not able to compete favorably with the lighter soils on a commercial basis.

Potatoes. The most favorable potato soils are probably the Merrimac sandy loam, Merrimac fine sandy loam, Enfield, Manchester and Hartford series, as well as the lighter phases of the Wethersfield and Charlton series. The Gloucester and Hinckley soils, due to their irregular topography and the high percentage of stone and gravel in the soil, are unfavorable for the special planting, spraying, and harvesting machinery that must be used.

Tobacco. The most important tobacco soils, as has been shown by data already given, are the Merrimac sandy loam and fine sandy loam, the Enfield very fine sandy loam, the Manchester fine sandy loam, and to a less extent, the Wethersfield and Cheshire fine sandy loams. The Merrimac coarse sand, when not too excessively sandy, is suited to the production of shade tobacco, but is of little value for the sun-grown crop.

Alfalfa. When properly limed and fertilized, alfalfa may be produced successfully on almost all the well-drained soils. The heavier phases of the Charlton and related series might produce some winter killing. The Gloucester, Hinckley and sandy Merrimac soils, although capable of producing good alfalfa, will probably be less used for this purpose because of the smaller development of the dairy industry upon them.

Grass hay. The heavier upland soils, chiefly of the Charlton group, will stand preeminently as best suited for grass hay. The Wethersfield, Dover and Suffield soils are probably next in order. The Gloucester soils will be kept in grass hay for much of the time, in spite of their lower productivity. Their difficulty of cultivation discourages their use for tilled crops except when the land is not absolutely required in order to furnish sufficient corn silage to support the small-scale dairies that are usually found on these soils. The grass hay crop is thin and shortlived on the sandy or gravelly soils of the Merrimac, Hartford, Manchester and Hinckley series. The alluvial Podunk soils, when not too poorly drained, are well adapted to the production of grass hay.

Corn. The corn crop, except for a few centers of seed production, is closely related to the demands of the dairy industry and the largest utilization of land for the corn crop will be on the Charlton, Wethersfield, Hollis, Dover and Suffield soil groups. The present practice of heavy manuring, if supplemented by adequate commercial fertilizers, should produce good corn crops on a wide range of soils.

Pasture. The Charlton, Suffield, Dover and Wethersfield groups are capable of producing good pasture, especially when improved by top-dressing treatments. The Gloucester areas now in pasture are excessively leachy and otherwise possess lower natural fertility, besides being so stony and irregular in topography that improvement is difficult. They cannot be plowed up for reseeding, and results of top dressing on such soils show little improvement, perhaps due to the excessively leachy character of the soil. The gravelly and sandy soils such as the Hinckley and Merrimac are very low grade pasture producers.

Forest. The larger areas of forest land are obviously to be found on the stony and rough areas. The Gloucester stony soils, the closely related Hinsdale and Brookfield series, and the Holyoke soils of the trap rock ridges are predominant on all the large forests of the state. Smaller areas of woodland cover from 10 to 50 per cent of other soil types. The use of the better agricultural soils for forest is dependent upon local topographic irregularities, inaccessibility of location and economic conditions that do not favor the utilization of all the better areas for crops or pasture. The stony tendency of pasture areas to revert to woodland when not cleared by now expensive labor, is an important factor which fre-

quently operates on even the best soils for pasture production. Some of the better soils may be cleared anew, but at the same time areas of the excessively stony, gravelly and sandy soils should logically revert to forest, through either natural or artificial methods. More than 50 per cent of Connecticut is absolute forest land; probably 15 per cent is of marginal type, the use of which for forest will depend upon fluctuating economic conditions. Problems relating to the proper use of soils for the various forest types are being jointly investigated by the Soils and Forestry Departments, and the present status of these studies will appear in a bulletin now in preparation.

Land utilization for purposes other than agriculture: While such use is not directly related to soil, there are cases where it may become a factor. Most towns and cities occupy land of favorable topography and drainage, and hence compete with agriculture for some of the best land. Recreational land, on the other hand, is rarely good farm land in this region, since rugged wooded hills, rocky shores and forest-circled lakes are the favored sites for park purposes. Country estates, golf courses, polo fields and the usual divertisements of the well-to-do are taking up an increasing proportion of our better agricultural land, particularly in Fairfield County, some parts of Litchfield County, and some of northeast Windham County, as well as the vicinity of our larger cities.

As a result of these surveys supplemented by reconnaissance work over the entire state, we have prepared the following table, which gives a general picture of the relative importance of the various soils for different land uses:

Table VII. Estimated Area and Land Use of Connecticut Soils, A.

Soil names	Crop A.	Pasture A.	Wooded A.	Urban, etc. A.	Total A.	%
Gloucester, Coloma, etc.						
f. s. l. and l.	65,000	40,000	155,000	10,000	270,000	8.7
stony phases	30,000	105,000	560,000	10,000	705,000	22.6
Brookfield, Hinsdale, etc.						
l. and f. s. l.	7,000	5,500	16,500	1,000	30,000	1.0
stony phases	10,000	40,000	394,000	6,000	450,000	14.4
Dover, Lenox, etc.						
f. s. l. and l.	12,000	8,000	5,000	2,000	27,000	0.9
stony phases	500	3,500	1,500	500	6,000	0.2
Charlton, Hollis, etc.						
l. and f. s. l.	185,000	85,000	85,000	35,000	390,000	12.5
stony phases	20,000	52,500	70,000	7,500	150,000	4.8
Wethersfield, Cheshire, etc.						
l. and f. s. l.	150,000	40,000	50,000	60,000	300,000	9.7
stony phases	500	5,000	28,500	2,000	36,000	1.2
Whitman, Peru, etc.						
l. and f. s. l.	4,000	8,000	8,000	1,000	21,000	0.7
stony phases	2,000	12,000	38,000	2,000	54,000	1.8
Hinckley, Manchester, etc.						
gravel and sand	3,000	6,000	14,000	10,000	33,000	1.1
s. l. and f. s. l.	20,000	6,000	20,000	20,000	66,000	2.2

Soil names	Crop A.	Pasture A.	Wooded A.	Urban, etc. A.	Total A.	%
Enfield						
v. f. s. l.	26,000	3,000	5,000	5,000	39,000	1.3
Merrimac, Hartford, etc.						
s. l. and l. s.	64,000	8,000	24,000	30,000	126,000	4.0
l. and f. s. l.	12,000	5,000	10,000	15,000	42,000	1.4
coarse sand	10,000	1,500	22,500	5,000	39,000	1.3
Suffield, etc.						
si. l. and cl. l.	15,000	12,000	6,000	6,000	39,000	1.3
Podunk, etc.						
l. and si. l.	17,000	19,000	18,000	6,000	60,000	2.0
Muck, etc.	3,000	12,000	82,000	2,000	99,000	3.3
Tidal marsh—18,000 A.	.....	.....	.....	.....	18,000	0.6
Rough stony land	.....	.....	90,000	.....	90,000	3.0
	656,000	477,000	1,703,000	236,000	3,090,000	100.0

A tabulation of the soils on 190 dairy farms in seven towns of the Eastern Highland indicates the relative importance of soils of the 16 series which were there identified, as shown in Table VIII. "Improved land" in this table includes cultivated crops, hay fields, open pasture and farmstead sites.

TABLE VIII. SOIL SERIES AND IMPROVED LAND DISTRIBUTION ON EASTERN CONNECTICUT DAIRY FARMS.

Series	Percentages: Of series in improved land	Of improved land in series	Of all farm land in series
Charlton	44.03	25.40	16.88
Gloucester	18.25	18.21	29.19
Merrimac	80.14	14.25	5.20
Taugwank	41.34	10.17	7.20
Coloma	45.41	9.08	5.85
Hinckley	23.30	8.39	10.54
Brookfield	26.81	7.31	7.98
Whitman	9.23	3.30	10.47
Peru	49.56	1.34	0.79
Plymouth	22.47	1.32	1.72
Podunk	67.19	0.41	0.18
Muck	3.49	0.30	2.52
Hinsdale	7.38	0.26	1.02
Ondowa	100.00	0.12	0.03
Sutton	100.00	0.09	0.03
Scarbro	100.00	0.05	0.02

The last three series are represented in such small areas as to be of no significance. For the other soils, the degree of improvement is nearly what one should expect from their stoniness, topography, and moisture conditions as affected by texture, organic content and the character of the substratum. Apparently a superior natural supply of plant nutrients is either not characteristic of any of these soils, or has little relationship to their selection for agricultural use.

PART III

A CRITICAL STUDY OF THE CHEMICAL COMPOSITION OF REPRESENTATIVE CONNECTICUT SOILS

Soil investigators of two or three decades ago hoped that it would be possible to determine the fertilizer requirements of soil through chemical analyses of soil samples, and many attempts were made to correlate such analytical results with field productivity. The results were disappointing in most instances, and a strong prejudice was built up against the use of chemical soil analyses as a guide in soil diagnosis.

However, the rapid developments in science during recent years have furnished many new tools for attacking the very complex problems of soil chemistry and its relationships with the nutritional requirements of crop plants. While we are yet far from a solution of many important questions, it is now believed that a detailed knowledge of the chemical soil characteristics is a definite aid to the intelligent use of fertilizers, lime and other soil amendments.

During the past five years a large number of representative samples of the important soil types of the state under various cropping systems has been under chemical investigation. The results of these studies are here briefly summarized and will be discussed under headings referring to the particular element or characteristic in question.

Organic Matter and Nitrogen

Organic matter and nitrogen are so closely related in agricultural soils that no permanent change in one can be effected without a corresponding change in the other.

The surface soils of this state, with the exception of forested soils, contain organic matter and total nitrogen in a fairly definite ratio. More than 100 soils for which both the nitrogen and organic matter (computed from total organic carbon) were determined, gave an average value of one part of nitrogen to 20 parts of organic matter, with fluctuations between the limits of 1:16 and 1:25. This is in agreement with the results of Sievers[1] on some typical Massachusetts soils. It thus follows that the total nitrogen content is a good measure of the organic content of the soil, and that a soil with 0.2 per cent of nitrogen contains approximately four per cent of organic matter.

In most cases results of chemical analyses of surface soils are here reported as pounds per acre on the basis of a conventional rule that an acre of soil to plow depth contains approximately 2,000,000 pounds of dry soil. Pounds per acre may be calculated to per cent by dividing by 20,000. Thus 4,000 pounds per acre represent 0.2 per cent of the dry weight of the soil.

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[1] Sievers, F. J., Jour. Am. Soc. of Agron., 22: 10-13, 1930.

TABLE IX. NITROGEN CONTENT OF CONNECTICUT SOILS.

	No. of soils	Average: Total percentage	Average: Nitrogen content lbs. per A. of surface soil	Min. and max. range lbs. per A.
General crops and mowing				
Gloucester f. s. l. and loam ...	13	.243	4874	1990-9635
Brookfield f. s. l. and loam	8	.20605	4121	2486-5670
Charlton f. s. l. and loam	25	.23530	4706	2650-9850
Wethersfield f. s. l. and loam ..	8	.12260	2452	1590-3622
Dover f. s. l.	2	.12270	2454	1860-3048
Whitman loam	4	.31160	6232	5850-6950
Taugwank loam	5	.25410	5082	2740-7320
Merrimac f. s. l.	4	.12950	2590	1550-5126
Hinckley gravelly loam	3	.31010	6202	4240-8795
Hartford f. s. l.	3	.16780	3356	2420-3850
Suffield clay loam	2	.18175	3635	3290-3980
Podunk silt loam	25	.11600	2320	1200-3580
Weighted average		.24210	4842	1200-9850
Permanent pasture land				
Gloucester f. s. l. and loam	17	.20235	4047	2930-5362
Brookfield loam	2	.22875	4575	4340-4810
Charlton f. s. l. and loam	21	.26275	5255	3350-7366
Wethersfield f. s. l. and loam ..	6	.19550	3910	2580-6796
Becket f. s. l.	2	.27370	5475	5450-5500
Whitman loam	2	.34605	6921	6220-7622
Suffield clay loam	3	.14780	2956	2346-3516
Merrimac loamy sand	2	.07040	1408	1266-1550
Other soils	5	.21560	4312	2272-6674
Weighted average		.22295	4459	1266-7622
Tobacco land				
Merrimac f. s. l. and sandy loam	29	.14630	2926	2300-4100
Merrimac loamy sand	20	.13210	2642	1560-3100
Wethersfield loam	12	.15420	3084	2166-4170
Enfield v. f. s. l.	10	.13450	2690	2150-3575
Scarbro loam	8	.27650	5530	4966-6366
Weighted average	79	.15560	3112	1560-6366
Barren and other waste land				
Sand barrens of Wallingford and Windsor	4	.05060	1012	386-1545
Old field types	6	.1777	3554	2830-4416

There is a wide range in the nitrogen and consequently in the organic content of Connecticut soils, ranging from 386 to 9,635 pounds per acre of surface soil. (This does not include organic soils, such as muck, peat and tidal marsh.) The average for all soil types of the various cultural groups is approximately 0.2 per cent, equivalent to 4,000 pounds per acre of surface soil.

It is of interest to compare these figures with soils of other regions.

TABLE X. NITROGEN CONTENT OF OTHER SECTIONS OF EASTERN UNITED STATES.

	Percentage of nitrogen in surface soil
165 Coastal plain soils of N. C.	.039
71 Piedmont soils of N. C.	.048
381 Kentucky soils	.120
485 West Virginia soils	.150
125 Ohio soils	.187
105 New York soils	.207
30 Minnesota soils	.338

It is thus seen that the soils of Connecticut as a class compare quite favorably with those of other states and are much higher than those of states further southward.

In a comparison of cultural groups, soils in general crops and mowing, chiefly on dairy farms, contain the highest amounts of nitrogen (4,842 lbs. per acre). The pasture soils are somewhat lower (4,459 lbs.) while the tobacco soils chiefly of sandy texture and lying within the central lowland area of the states, are distinctly below the average (3,112 lbs.).

Of the various soil types within the respective cultural groups, the poorly drained soils, like the Whitman and Scarbro soils, are highest in nitrogen, with Charlton and Gloucester types above the general average, while the Wethersfield and Merrimac soils are definitely lower in nitrogen content. Beyond these generalizations, there is an insufficient number of soils of any one type to justify any definite conclusions.

It does not appear that soils of average texture have suffered any serious decline in nitrogen content in the 200 years or more of agricultural use. The nitrogen content of 21 forest soils to the depth of seven inches, and including any litter which may occur on the forest floor, gives an average of 0.205 per cent nitrogen, which is almost identical with the average of the agricultural soils. Certain excessively sandy soils have undoubtedly suffered some depletion in organic matter and nitrogen content as was found to be the case in a special study of the organic matter of tobacco soils.[1]

The humus and nitrogen requirements of Connecticut soils. The benefits derived from an adequate supply of organic matter are manifold. Excessively sandy soils are improved in moisture-holding and plant food-absorbing capacity. Heavy clay soils are made less difficult to cultivate. Micro-organisms require energy material from decomposing organic matter and plant food constituents, chiefly nitrogen, are liberated by its decomposition.

The present supply of organic matter is adequate to meet these

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[1] Morgan, M. F., Conn. Agr. Exp. Sta., Tobacco Substa. Bull. 10:66-71. 1927.

requirements on most soils of the state, but this does not remove the necessity for the continued conservation of a favorable humus supply in every way possible, through green manure crops and animal manures on intensively cultivated lands, the plowing under of sods that have been properly thickened by adequate fertilization, and the return to the soil of plant residues. As manure becomes less abundant, it may become increasingly difficult to maintain a favorable supply of organic matter, but the prospects for serious depletion are not as serious as in many other regions.

The relatively good nitrogen supply which is stored up in most Connecticut soils is a potentially valuable reserve but it should not be depleted by a corresponding decrease in humus content of the soil. Some crops on soils which have been investigated in greenhouse fertilization experiments have shown little or no response to nitrogen under the favorable temperature and the absence of leaching which occur under such conditions. This is due to a liberation of soil nitrogen which is not comparable to field results. Non-leguminous crops demand that nitrogen be added to the soil in commercial fertilizers, manure or the growth of legumes, to offset the rapid loss of liberated soil nitrogen through leaching and crop removal. Available fertilizer of nitrogen during certain periods of crop growth is needed to supplement the supply that naturally becomes available during that time, or to replace losses through leaching.

Soils which contain a relatively low total nitrogen content, such as the Merrimac and Wethersfield types, especially under continuous tobacco culture or intensive vegetable cropping, are in a more serious need of large amounts of fertilizer nitrogen than the upland soils such as the Gloucester and Charlton types under dairy farming or pasture conditions.

The Total and Available Phosphorus Supply in Connecticut Soils

Phosphorus, an element very commonly deficient in soils of eastern United States, exists in the soil in relatively small quantities, and the total amount rarely exceeds 0.15 per cent of the dry weight of surface soils. With figures ranging downward to less than 0.05 per cent, there is a very limited reserve supply and a serious danger of depletion if losses through crop removal and grazing are not replaced by fertilization.

Phosphorus is a relatively insoluble constituent in soils and the water-soluble phosphorus that can be leached or extracted from soils is so small that there is practically no loss through leaching. However, some of the soil phosphorus is in combinations that become available for plant growth, even though it is not dissolved in the soil water. The determination of this available phosphorus

supply is a difficult chemical problem, and no completely satisfactory method for its measurement has been devised. However, our investigations have given a good general agreement between the amount of phosphorus which is dissolved from the soil by N/100 sulfuric acid (obtained by five minute digestion of 10 grams of soil with 100 cubic centimeters of the dilute acid solution) and the response of crops to phosphorus treatments under greenhouse conditions. The values here reported as "available" phosphorus were obtained by this method.

TABLE XI. THE TOTAL AND AVAILABLE PHOSPHORUS IN CONNECTICUT SOILS.

		Pounds per acre in surface soil			
		Total phosphorus		Available phosphorus	
	No. of soils	Average	Min. and max. range	Average	Min. and max. range
General crops and mowing					
Gloucester f. s. l. and loam ..	13	1817	1508-2404	8.5	2. —24.2
Charlton loam and f. s. l.	25	1996	1080-3638	9.14	2. —24.0
Wethersfield f. s. l.	8	1378	898-2168	16.57	2. —38.0
Brookfield loam	8	1975	970-3400	6.18	2. —23.0
Taugwank loam	5	1538	622-2440	2.70	1.8 — 5.0
Merrimac f. s. l.	4	2094	1660-2670	14.75	6. —23.0
Whitman loam	4	2055	1532-2588	2.43	1.9 — 3.0
Hartford sandy loam	3	1761	1218-2510	22.50	20. —25.
Dover f. s. l.	2	1690	1612-1768	30.5	30. —31.
Suffield clay loam	2	1331	1121-1540	7.5	5. —10.
Podunk silt loam	25	1756	648-2926	16.7	0.5 —36.
Weighted average		1819	622-3638	10.26	0.5 —38.
Pasture					
Gloucester f. s. l. and loam ..	17	1739	612-5150	3.67	2.0 — 8.25
Charlton loam and f. s. l.	21	1677	567-3260	3.91	1.25—12.00
Wethersfield f. s. l.	6	1901	1456-2430	4.62	2.4 — 6.2
Brookfield loam	2	2165	1448-2884	2.4	2.0 — 2.8
Beckel f. s. l.	2	977	844-1110	2.9	1.4 — 4.4
Whitman loam	2	1181	800-1562	3.05	2.9 — 3.2
Suffield clay loam	3	1227	1135-1360	3.55	2.25— 5.7
Merrimac loamy sand	2	1321	932-1710	10.5	6. —15.
Other soils	5	2275	1545-3700	4.55	2. — 8.
Weighted average		1709	612-5150	4.06	1.25—15.
Tobacco land					
Merrimac sandy loam	12	2890	1376-4080	39.72	16.5 —60.
Enfield v. f. s. l.	3	3480	2530-4430	45.0	28. —62.
Other soils, unclassified	48	3260	1750-4960	44.0	25. —63.
Weighted average		3200	1376-4960	42.5	16.5 —63.
Barren and other waste land					
Sand barrens of Wallingford and Windsor	4	842	502-1284	6.25	3. —11.
Old field types	6	1513	980-2220	5.3	1. —13.4

With respect to phosphorus, both total and available, the soils of the state are also extremely variable, the total amount ranging from 502 to 5,150 pounds per acre, while the "available" phosphorus as measured by laboratory tests ranges from 1 to 63 pounds. The

average for the state is 1,838 pounds of total phosphorus, equivalent to 0.0919 per cent in the surface soil, and an availability test of 9.84 pounds per acre.

Results of the availability tests used at this station are not directly comparable to those reported from other states, but the following table gives a fair comparison of the conditions of total phosphorus supply.

Table XII. Total Phosphorus Content of Soils in Other States.

	Total phosphorus in surface soil, percent
Kentucky "Bluegrass" soils	0.470
West Virginia, 485 soils	0.052
Illinois, light colored prairie soils	0.060
Illinois, heavy black prairie soils	0.100
Ohio, 126 soils	0.056
New York, average loam	0.074
New Jersey, 14 soils similar to Conn. types	0.073

The total phosphorus content of Connecticut soils is at least as good as, if not above the average of soils in other states, with the exception of the "bluegrass" region of Kentucky and the highly fertile black prairie soils.

In a comparison of cultural groups, soils in tobacco for a period of years are very significantly higher than the other soils of the state. This has been explained in a previous publication[1] on the basis of phosphorus accumulation from heavy fertilization in excess of crop requirements. There is little significant difference between the total phosphorus content of general crop lands and pasture although the average is slightly lower for the latter group.

As between soil types, there appears to be no consistent difference, with the exception of the very infertile barren sand areas in Wallingford and Windsor.

The phosphorus requirements of Connecticut soils. Although the total amounts of phosphorus in most Connecticut soils do not indicate a serious depletion, the availability of the native soil phosphorus is very low in all soils that have not been so heavily fertilized as to produce a surplus of the more available phosphorus in fertilizer residues. This condition has been definitely proven, both by laboratory tests and by fertilizer experiments in both greenhouse and field. The pasture areas, which have rarely received any fertilizer in return for the removal of available phosphorus in animal growth and milk production, are in the most serious condition in this respect. The average of 60 typical pasture soils of the state shows a phosphorus test of only about four pounds per acre,

[1] Anderson, P. J., Morgan, M. F., and Nelson, N. T., Conn. Agr. Exp Sta., Tobacco Substa. Bull. 7. 1927.

as compared to 10 pounds for the general crop and mowing land soils of the state and the very high average of 42.5 pounds for the heavily fertilized tobacco soils. This confirms the results of the Storrs pasture experiment[1] and the numerous pasture fertilizer trials conducted by the Extension Division of the Connecticut Agricultural College.

The general crop and mowing lands, while less seriously depleted in available phosphorus than the pasture lands, are still very seriously in need of fertilizer phosphorus in most cases. The results of the analyses reported in Table XI and of greenhouse results, shown in Tables XXII, XXV, XXIX and XXXII, are supplemented by an extensive survey of phosphorus availability on the fields of a large number of dairy farms in southeastern Connecticut. Of more than 300 fields in the towns of Stonington, North Stonington and Griswold, 87.4 per cent showed tests of 10 pounds or less of phosphorus per acre, and on all such fields we should reasonably expect a marked response to fertilizer phosphorus for almost any crop.

The conditions on all land that has been under heavy tobacco fertilization for a number of years have justified a recommendation of a practical decrease in the rate of application of "phosphoric acid" from the 160 to 200 pounds per acre which has been common in recent years, to as low as 100 pounds per acre. On new tobacco land not previously so heavily fertilized, the higher amounts should be continued for at least the first few years, until a substantial reserve has accumulated. The failure of old tobacco fields, such as the Tobacco Substation field at Windsor, to show significant response to phosphorus fertilization is not due to the low phosphorus requirements of the crop, since tobacco is extremely sensitive to a lack of adequate amounts of available phosphorus in the soil.

A similar condition probably exists on lands that have been very heavily fertilized for potatoes and vegetable crops, and in many such cases the common use of amounts in excess of 100 pounds per acre of "phosphoric acid" in the fertilizer may not be justified.

Total and Replaceable Potassium Supply of Connecticut Soils

Potassium (indicated in fertilizer formulae under the term "potash") exists in most soils in relatively large amounts as compared to nitrogen and phosphorus. On the other hand, most of the total potassium content of the soil is of a very insoluble character, existing in the form of the complex alumino-silicates of rock minerals. In a much more available form, a small part of the total potassium content of the soil occurs in the so-called "replace-

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[1] Brown, B. A., and Slate, W. L., Storrs Agr. Exp. Sta. Bull. 155. 1929.

able" or "exchange" condition, being absorbed by the colloidal material of the soil, from which it may be liberated by washing the soil repeatedly by solutions of neutral salts or of dilute acids.

Measurements of available potassium in the soil by chemical means are very difficult. Very little exists in water-soluble form, on account of the absorbing power of the finer particles of the soil for this element. With soils of similar physical character, differences in amounts of "replaceable" potassium are usually associated with differences in "potash" availability.

TABLE XIII. THE TOTAL POTASSIUM CONTENT OF CONNECTICUT SURFACE SOILS.

	No. of soils	Average Percent	Average Lbs. per A.	Min. and max. range—lbs. per A.
General crops and mowing				
Charlton loam and f. s. l.	25	1.4260	28,952	15,791-44,760
Gloucester f. s. l.	13	1.1717	23,435	11,244-31,292
Brookfield loam and f. s. l.	7	1.5557	31,114	16,980-42,483
Wethersfield f. s. l. and l.	6	1.4154	28,108	21,760-31,924
Taugwank loam	3	1.2512	25.024	16,659-35,678
Merrimac f. s. l.	4	1.7090	34,180	20,028-47,032
Suffield clay loam	2	2.5743	51,487	50,877-52,098
Podunk silt loam	25	2.0060	40,120	29,720-57,640
Other soils, unclassified	7	1.2957	25,914	16,723-35,700
Weighted average		1.4273	28,546	11,244-57,640
Permanent pasture land				
Charlton loam and f. s. l.	21	1.5853	31,707	21,700-43,920
Gloucester f. s. l.	16	1.4973	29,946	17,109-43,856
Wethersfield f. s. l. and l.	6	1.4194	28,388	19,425-35,280
Merrimac loamy sand	2	0.8989	17,979	17,660-18,299
Suffield clay loam	2	2.3235	46,471	42,901-50,041
Whitman loam	2	1.1827	23,653	23,509-23,798
Other soils, unclassified	8	1.5862	31,724	21,193-43,770
Weighted average		1.5300	30,600	17,109-50,041
Tobacco land				
Merrimac sandy loam	5	1.2013	24,027	13,720-28,658
Enfield v. f. s. l.	2	1.3218	26,436	....
Average	7	1.2215	24,430	13,720-28,658
Sand barrens and waste land	8	1.3710	27,420	19,104-40,944

Although the total potassium content of Connecticut soils shows considerable variation, the proportionate range is not as great as for the other chemical constituents previously discussed. The state average of approximately 29,000 pounds per 2,000,000 pounds of surface soil, is similar to the potassium content of soils of similar texture in other parts of the country.

There appears to be a general correlation between the texture of the soil and the total potassium content. The lighter textured sandy loam soils of the tobacco district are lower, as a class, while the heavier podunk silt loam and Suffield clay loam are higher in potassium. However, there are individual fields of loam and fine sandy loam texture that are lower than some of the most barren

areas of sand. A large proportion of the sand grains of the sandy soils of this state are composed of minerals that contain potassium (such as fragments of muscovite mica and orthoclase feldspar). This is not so commonly true of the sandy soils of other regions, particularly of the Atlantic coastal plain, where the larger sand grains are chiefly of quartz.

The potassium requirements of Connecticut soils. In spite of their high amounts of total potassium, the soils of this state that have not been liberally fertilized or manured are commonly so deficient in available potassium that most crops grown upon them are apt to suffer from a deficiency in this element. This condition is suggested by the results of "replaceable" potassium determinations reported in Table XIV and confirmed by the results of greenhouse and field trials, Tables XXIII, XXVI, XXX and XXXII.

Table XIV. Replaceable Potassium in Some Connecticut Soils.

	Replaceable potassium		
	Average		Min. and max. range
	Percent	Lbs. per A.	lbs. per A.
General crops and mowing, 33 soils from 12 soil types	.00684	136.80	51.46- 474.36
Pasture land, 14 soils from 8 soil types	.00620	124.40	33.72- 239.50
Tobacco, 7 soils	.02356	471.20	133.46-1961.76

The number of soils of any particular soil type was not sufficient to justify any classification on this basis, and there did not appear to be any consistent correlation for any soil type.

However, the effects of previous heavy fertilization are noticeable in case of the soils from tobacco land, which as a class have the lowest total potassium content because of their sandy texture, while their replaceable potassium is much higher than in soils from pasture land and general crops. On the other hand, tobacco fertilization that provides very liberal amounts of potash is justified on the basis of the high potassium requirements of this crop and the considerable leaching losses of potassium from such soils.

Since most vegetables and potatoes are quite sensitive to deficiencies in potash availability in the soil, fertilizers for such crops practically disregard the reserve of this element in the soil. With liberal applications of manure, the use of more than 80 pounds per acre of fertilizer potash for these crops should be adequate, while on sandy soils and with little or no manure as much as 150 pounds per acre may be profitable.

Corn and grass hay on dairy farms may not suffer from lack of potash if the land is well manured, but the results of pot experiments on soils from such fields, reported later, provide strong arguments in favor of the more general use of fertilizer potash. Alfalfa may be expected to respond to "potash" on most soils, and the use

of from 100 to 125 pounds of potash per acre on land that is to be seeded to alfalfa is an insurance against a strong possibility of deficiency in this respect.

The potassium situation on permanent pasturelands of the state is still a rather open question. The Storrs pasture experiment has shown little response to potash fertilization, and in general it is believed that until adequate amounts of limestone and superphosphate have been used, the pasture soils will not respond to this element. A high level of productivity of pasture herbage may not be possible on many soils until potash is also used.

Calcium and Magnesium Content of Connecticut Soils

With the exception of a few small areas of the Dover series in western Connecticut, the soils of the state contain calcium and magnesium that is not derived from the decomposition of limestone, but is liberated from the slow weathering of complex silicates such as soda-lime feldspar and ferro-magnesian minerals. Thus, although the soils are predominantly acid, there may be a fair amount of total calcium and magnesium in the soil composition.

Table XV. Total Calcium and Magnesium of Content of Connecticut Soils.

		Pounds per acre of surface soil			
		Calcium		Magnesium	
	No. of soils	Average	Max. and min. range	Average	Max. and min. range
General crops and mowing					
Charlton	16	20,495	11,840-36,800	11,654	5,951-26,100
Gloucester	10	22,759	13,680-26,683	10,182	6,405-13,671
Brookfield	5	23,057	9,902-36,960	16,889	4,886-31,446
Wethersfield	4	11,505	10,720-12,160	8,453	5,450-12,480
Taugwank	3	24,327	18,240-30,262	9,669	6,640-14,195
Other soils	6	24,070	12,160-34,818	17,845	4,824-32,572
Average	44	21,232	9,902-36,960	12,332	4,824-32,572
Pasture land					
Average	11	20,487	10,760-44,740	10,431	4,196-18,760
Tobacco land					
Merrimac sandy loam	5	14,736	11,540-20,160	6,127	4,760- 7,200
Enfield v. f. s. l.	2	17,570	17,440-17,700	8,360	6,859- 9,860
Sandy barrens and other waste land	..	12,947	10,000-15,260	7,177	5,420- 8,340

The average calcium content is 19,827 pounds and the magnesium content 11,140 pounds, per 2,000,000 pounds of surface soil. The variation is considerable, especially in the magnesium content.

The chief difference in cultural groups is the consistently lower figures of both calcium and magnesium for the soils of the tobacco district. (These do not include any samples of soil from the

Housatonic Valley tobacco section, where the opposite conditions may occur.) Many tobacco soils do not naturally contain sufficient available calcium and magnesium for best quality of the cigar ash, and the tobacco plants on some of the sandier soils show actual magnesium deficiency symptoms.

It is doubtful if calcium is ever an actual limiting factor in crop yields on Connecticut soils. Except in the case of tobacco, lack of available magnesium is not known to be a cause of poor yield in this state. However, Jones[1] has found a type of chlorosis in corn which is associated with magnesium-hunger on a soil at the Massachusetts Agricultural Experiment Station.

On the other hand, the "replaceable" calcium in soils is often rather low, especially on highly acid soils. In such cases the absorptive capacity of the soil for bases ("base exchange capacity") is not fully satisfied, and since calcium represents approximately 80 per cent of the exchangeable bases, a base-unsaturated acid soil would show a low value for replaceable calcium.

This is evidenced in the following table.

Table XVI. Replaceable Calcium and pH of Certain Connecticut Soils.

Replaceable Calcium in Pounds per 2,000,000 of Surface Soil.

Group	Average	pH Average	No. of soils
0— 499	302.68	4.87	13
500— 999	717.03	5.00	20
1000—1999	1408.00	5.12	18
2000+	2792.00	5.84	6

There were no evidences of correlation between replaceable calcium and either soil type or cultural class. There were wide variations in soil acidity, as expressed in pH, for soils of similar replaceable calcium content, but there was a general trend toward high acidity with low replaceable calcium.

The Acidity of Connecticut Soils

Most soils of this state are naturally acid, and except for certain areas of the Dover series where limestone outcrops lie near the surface, soils that have not received lime or limestone applications are almost certainly acid. The conditions of Connecticut soils with respect to acidity and lime requirement have been extensively studied. A previous publication[2] summarizes tests of more than 2,000 tobacco fields in the Connecticut Valley. Nearly 1,500 fields in general farm crops and mowing, distributed over 190

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[1] Jones, J. P., Jour. Agr. Res. 39: 873-892. 1929.

[2] Morgan, M. F., Conn. Agr. Exp. Sta. Bul. 306. 1929.

farms in the towns of Griswold, Woodstock, Coventry, Brooklyn, Columbia, Stonington, North Stonington and Canterbury, have been examined for soil acidity. These results are supplemented by the results of tests of the soils that have been analyzed for all important constituents in this laboratory, besides those of more than 500 soils that have been sent in by farmers and gardeners during the past five years.

It is obviously unnecessary to present the individual results of all these tests, and the large number of samples for which we have record justifies the following conclusions:

1. With the exception of soils closely related to limestone outcrops in certain parts of western Connecticut, indicated as the "Dover" soil area on the accompanying soil map, there is no relationship between soil type and soil acidity. In other words, no one soil type is naturally more acid than another.

2. For equal degrees of acidity as measured by the pH test, there is a correlation between lime requirement and the textural and organic characteristics of the soil. Sandier soils at the same pH require less lime to correct the acidity than more loamy or clayey soils, while soils with much organic matter require more lime than those with a lower organic content. This is fully discussed from a technical viewpoint in a journal paper.[1]

3. The previous cultural history is the chief factor in determining the present degree of acidity of the soil. As a group, the [illegible] soils are slightly more acid, with an average of 4.91 pH. Until t[illegible]w years lim[illegible] was never applied to permanent pasture land, and as yet [illegible] such areas have been limed.

Little difference exists between the average figures for tobacco soils (5.37 pH) and for the fields in general crops and mowing (5 39 pH), although the latter group includes 13.4 per cent which ha[illegible]e been limed to reaction of above 6.2 pH, and on the tobacco soils only about four per cent of the fields lie above this limit. Tobacco farmers have rightly avoided the use of heavy lime applications, which favor the black root rot organism.

Gardens and fields used for vegetable crops have usually been limed heavily, and are rarely found to be strongly acid.

The lime requirements of Connecticut soils. The amount of lime that should be used on any particular field is determined by four factors:

1. The acidity of the soil, such as measured by pH tests.
2. The textural character of the soil.
3. The organic content of the soil.
4. The optimum reaction for the crop to be grown.

The relationship between the acidity of the soil and its lime requirement as affected by texture and organic content is indicated by the following table:

[1] Morgan, M. F., Soil Sci., 29: 163-180. 1930.

Table XVII. Limestone ($CaCO_3$) Required to Neutralize Soil Acidity Under Average Connecticut Conditions (In Tons Per Acre).

Soils testing between following pH limits	Very sandy soils		Sandy loams		Loams and fine sandy loams		
	Low O.M.[1]	Medium O.M.	Low O.M.	Medium O.M.	Low O.M.	Medium O.M.	High O.M.
3.80-4.19	1.50	2.25	2.55	3.15	3.50	4.40	5.35
4.20-4.59	1.30	1.95	2.21	2.73	3.00	3.80	4.65
4.60-4.99	1.10	1.65	1.87	2.31	2.50	3.20	3.95
5.00-5.39	0.90	1.35	1.53	1.89	2.25	2.70	3.25
5.40-5.79	0.70	1.05	1.19	1.47	1.75	2.10	2.55
5.80-6.19	0.50	0.75	0.85	1.05	1.25	1.50	1.75
6.20-6.59	0.30	0.45	0.51	0.63	0.75	0.90	1.05
6.60-6.99	0.10	0.15	0.17	0.21	0.25	0.30	0.35

A discussion of the specific reaction preferences and crop lime requirements is not within the scope of this bulletin. However, the following general statements indicate the situation of the state as a whole with respect to the need for lime in growing the economically important crops.

1. About 15 per cent of the improved land of the state is so acid that all crops grown are a practical failure because of the high acidity of the soil.
2. Sixty per cent of the Connecticut fields are so acid that corn and grass hay would probably be benefited by liming.
3. Seventy-five per cent of the land does not grow clover well on account [illegible]eeds.
4. Alfa[illegible]d acid sensitive vegetable crops could not be grown on 90 per cent [illegible] Connecticut soils without liberal lime applications.
5. Only one per cent of the total improved area of the state is now limed to the point where no soil acidity exists.
6. Practically all permanent pasture lands must be limed as the first step in pasture improvement before superphosphate and other fertilizers can produce a material benefit.
7. About 70 per cent of fields used for tobacco are at a favorable soil reaction for that crop. About 20 per cent of these soils are so acid that moderate lime applications should be beneficial, while ten per cent have been too heavily limed in the past, with serious black root rot troubles as a consequence. Light applications of magnesian lime might improve the quality on most of the balance of the area.
8. Lime has usually been liberally used on fields devoted chiefly to vegetable crops and the main use of lime in this type of farming will be for maintaining these fields at the present favorable reaction and for new fields not previously limed.

Aluminum and Manganese as Soil Toxins in Acid Soils

Under the strongly acid conditions such as have been shown to exist over much of the state, aluminum and manganese tend to form soluble compounds in the soil. It has been shown clearly at the Rhode Island Agricultural Experiment Station that the high concentration of soluble aluminum which exists in certain strongly

[1] O.M. stands for organic matter in above table, where
—low O.M. is indicated by light brown, yellowish-brown or reddish-brown color.
—medium O.M. is indicated by medium brown or gray brown color.
—high O.M. is indicated by dark brown or very dark grayish brown color.

acid soils of that state is quite poisonous to many crops, while soluble manganese is similarly injurious to some species of plants.

Connecticut soils frequently show considerable amounts of aluminum compounds which are soluble in N/2 acetic acid (so-called "active" aluminum). Twenty-five acid soils when studied under greenhouse conditions showed amounts of "active" aluminum ranging from 571.5 to 69 p.p.m. (parts per million) of Al (equivalent to from 1,080 to 130.4 p.p.m. of Al_2O_3) on soils ranging in acidity from 3.94 to 5.26 pH. Within this group of soils, six soils, testing above 4.8 pH, averaged 120.23 p.p.m. "active" Al, while nine soils testing below 4.2 pH averaged 336.6 p.p.m.

The amounts of water-soluble aluminum present in the soil are small but under strongly acid conditions can be readily detected. Water extracts from soils above 5 pH rarely give a positive test for aluminum, while at lower pH values, tests of leachates from the soil range from about 1 p.p.m., up to about 40 p.p.m., the higher values usually being found on the more acid soils.

Active manganese has also been determined by the half-normal acetic acid method for a number of Connecticut soils. Forty soils ranging from 3.94 to 6.0 pH gave "active" manganese (Mn) of from 0 to 409.0 p.p.m. A correlation between degree of acidity and "active" manganese is suggested in the following table.

Table XVIII. "Active" Manganese and Soil Acidity.

pH group	No. of soils	Average "active" Mn p.p.m.	Range
3.90—4.19	9	113.78	26.6—409.
4.2— 4.79	6	45.40	11.5—116.4
4.8— 5.20	8	21.80	6.0— 46.1
Above 5.20	7	3.16	0.0— 4.2

Manganese is present in the water extracts or leachates from strongly acid soils in appreciable concentrations. This is indicated by some preliminary data from the lysimeter at Windsor, and from analyses of leachates from greenhouse soil pots of different soils and treatments. Thus in a greenhouse experiment with tobacco, two and a half liters leached through 8,000 grams (dry weight) of a soil testing 4.5 pH, with tobacco showing marked symptoms of manganese toxicity, gave a concentration of 47.3 p.p.m. of manganese. The maximum thus far obtained in leachates from acid soils has been 70.5 p.p.m. Details of these studies on water-soluble manganese will be published later.

It is thus seen that Connecticut soils of strong acidity (below 5.0 pH) may contain sufficient amounts of both aluminum and manganese in forms that may be toxic to the growth of plants that are sensitive to soluble concentrations of either of these elements. It has been shown that tobacco is definitely injured by manganese poisoning through the soil, although this particular crop appears not to be affected by the soluble aluminum concentrations that normally exist in acid soils.

PART IV

NUTRIENT REQUIREMENTS OF CONNECTICUT SOILS AS MEASURED BY VARIOUS CROPS IN GREENHOUSE AND SOIL FRAME EXPERIMENTS

Beginning in a small way with limited facilities in 1924 and 1925, and as an important phase of the work since the construction of a new greenhouse in 1926, pot experiments have been conducted to study the fertilizer and lime needs of the important types of Connecticut soils. During this period 79 different soils have been under investigation. The various soil types and the kinds of fields from which the samples were taken are shown in Table XIX.

TABLE XIX. CHECK LIST OF SOILS USED IN GREENHOUSE POT TESTS.

	Laboratory serial numbers				
Soil type	General crops and mowing, plowed within last five years	Old mowing lots	Permanent pasture	Tobacco	Waste land
ucester fine sandy loam	4, 10, 315	7, 22, 320	228, 317, 335	....	1
ucester loam	316, 318, 319	......	......	....	....
oma very fine sandy loam	......	......	322	....	....
okfield fine sandy loam	17	......	......	....	....
ısdale fine sandy loam	......	236	......	....	....
lton fine sandy loam	229, 234	......	......	....	....
llis silt loam	......	234	......	....	....
ver fine sandy loam	14, 232	......	......	....	....
lyoke loam	......	......	235	....	....
ldletown loam	......	......	60	....	....
odbridge fine sandy loam	2, 15	5	225	....	....
ırlton fine sandy loam	8, 11, 311, 312	241	......	....	....
ırlton loam	3, 9, 12, 310	23, 313, 314	327, 340	....	....
ıgwank loam	234	237	......	....	....
ldam fine sandy loam	......	238	......	....	....
ox fine sandy loam	......	230	......	....	....
shire sandy loam	......	......	......	....	344
shire fine sandy loam	......	......	338	....	243
thersfield fine sandy loam	58	......	......	....	....
thersfield loam	20, 227	......	......	....	....
hfield loam	......	6, 16, 239	......	....	....
ket fine sandy loam	......	......	1	....	....
itman loam	......	240	......	....	....
ıckley gravelly sandy loam	......	......	242	....	....
ıckley fine sandy loam	......	......	241	....	....
ıckley loam	321	......	......	....	....
nchester fine sandy loam	......	......	336	....	....
rrimac coarse sand	......	......	......	....	19
rrimac loamy sand	......	......	224	223	21
rrimac sandy loam	......	......	......	244	....
tford coarse sand	......	......	......	....	343
ield very fine sandy loam	......	......	246	....	....
field clay loam	......	18, 245	337	....	....
lunk silt loam	......	325	......	....	....
lunk loamy sand	......	......	......	....	326

The geographical distribution of these soils is shown in Figure 63.

The soils are collected in the field during the autumn months. About 500 pounds of the soil at normal field moisture content are thoroughly mixed, passed through a one-quarter inch screen to remove the coarse gravel and stone, bagged and brought into the laboratory, where it is air-dried and potted in two gallon glazed earthenware pots with a hole for drainage and aeration at the

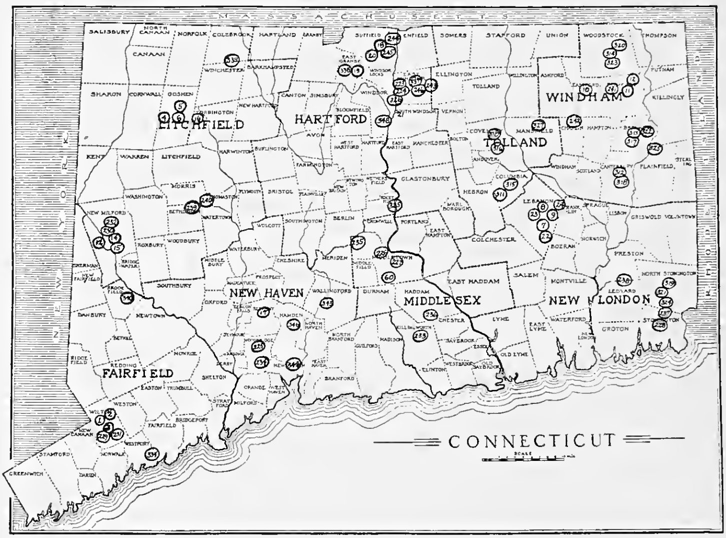


FIGURE 63. Locations of fields from which soils have been taken for fertilizer experiments in greenhouse plots and soil frames. The laboratory record numbers are indicated within the small circles.

bottom of the side. Lime in the form of precipitated chalk ($CaCO_3$) is added in amounts representing one and one-half the lime requirement as determined by the Jones laboratory method. The nutrient elements are applied in solution. The usual treatments per two gallon pot are as follows:

Nitrogen (N): 0.8 gm. urea.

Phosphorus (P): 1 gm. H_3PO_4 (85%).

Potassium (K): 1.5 gms. Potassium acetate.

Thus no other nutrient elements than N, P, and K are added in the fertilizer.

After applying the treatments the soils are made up to about 60 per cent water saturation, and seeded or planted about one week after the nutrient solutions are added.

Distilled water was used in 1924 and 1925, but as insufficient

amounts were available for the expanded greenhouse facilities in 1926, rain water collected from the laboratory roof was used for a time. This proved to be unsatisfactory because of its sulfur content and acid reaction, especially during the winter period when the nearby heating plant, burning soft coal, was in operation. The tap water from the city mains was found to contain only negligible quantities of any of the nutrient elements, and it has been used exclusively for watering the pots during the past three years.

It was originally expected that the unlimed soils would remain at practically the same reaction as when collected from the field. However, subsequent pH tests of the variously treated soils showed an increase in the acidity of unlimed soils when kept under greenhouse conditions without being subject to leaching or the periodic return of low-temperature conditions such as naturally occurs in the field.

This tendency toward increased acidity is most noticeable with the nitrogen treatments (in the form of urea). This is in agreement with results with urea previously reported by Swanback and Morgan.[1]

An illustration of this trend toward increasing acidity in pot experiments is indicated in the data for soils 310 to 325 in 1929.

TABLE XX. SOIL REACTION OF SOILS 310 TO 325 IN GREENHOUSE POTS, NOVEMBER 13, 1929.

Treatments	310 pH	311 pH	312 pH	313 pH	314 pH	315 pH
NK	4.02	4.81	4.07	4.10	4.46	4.54
NP	4.01	4.28	3.94	4.14	4.13	4.11
PK	5.26	5.50	4.78	4.80	4.96	5.12
NPK	4.60	5.03	4.43	4.31	4.66	4.45
Soil from field in autumn, 1928	5.04	5.36	4.79	4.92	5.17	5.27

	316 pH	317 pH	318 pH	319 pH	320 pH
NK	4.66	4.10	3.83	4.06	4.79
NP	4.10	3.91	3.76	4.00	4.32
PK	5.26	5.09	4.27	4.85	5.15
NPK	4.65	4.21	3.93	4.22	4.90
Soil from field in autumn, 1928	5.23	5.18	4.72	4.91	5.36

	321 pH	322 pH	323 pH	324 pH	325 pH
NK	4.20	4.91	4.90	4.23	4.03
NP	3.92	4.08	4 63	4.15	3.93
PK	4.86	5.57	5.50	5.34	4.80
NPK	4.20	4.95	5.23	4.31	4.11
Soil from field in autumn, 1928	4.73	5.24	5.36	4.93	5.06

[1] Swanback, T. R., and Morgan, M. F., Conn. Agr. Exp. Sta. Bull. 311: 264-268. 1930.

The increased acidity under the conditions of our pot experiments is apparently most marked in cases where nitrogen is added and either phosphorus or potassium is omitted from the treatment. The decreased plant growth, with a corresponding diminution of the removal of the soluble salts either added in the fertilizer or produced from the nitrification of the area, may explain this phenomenon.

At any rate, the results from lime treatments in these pot experiments must be interpreted on the basis of the reaction of the potted soil at the time when the crop is grown, rather than the original reaction of the soil when it was collected in the field. This has involved the periodic testing of the pH of the soil from each pot.

Alfalfa

Alfalfa was grown as a test crop on 48 of the soils listed in Table XIX. On only 14 of the soils (Nos. 233-246 inclusive) were the treatments so designed as to show response to nitrogen, since it was believed that this crop, being a legume, would show little or no response to that element. Under greenhouse conditions this proved to be the case, since soils 233 to 246 averaged 98 per cent yield with LPK as compared with 100 per cent on the LNPK and only two soils, Nos. 243 and 246, gave significant responses to nitrogen.

Lime. This was the most serious limiting factor on most of the soils, with an average yield of only 57 per cent without lime, as compared with 100 per cent where lime was applied.

The soils with reference to their response to lime may be grouped as follows, the reaction of the soil in the unlimed, fertilized pots being indicated:

TABLE XXI. GROWTH OF ALFALFA WITHOUT LIME ON COMPLETELY FERTILIZED SOILS AND THEIR REACTION.

Complete failure (less than 5% crop)		Practical failure 5-50% crop		Serious decrease in growth 50-90% crop				Little or no response to lime (90% crop or better)	
Soil No.	pH	Soil No.	pH	Soil No.	pH	Soil No.	pH	Soil No.	pH
234	3.92	2	4.76	1	5.11	19	4.94	3	6.26
237	3.88	224	4.81	5	4.94	20	5.51	3	5.98
239	4.25	225	4.65	6	5.11	21	5.52	10	6.58
243	3.78	228	4.67	7	4.92	22	5.44	14	7.08
		231	4.38	8	5.27	23	5.12	232	6.85
		233	4.76	9	4.96	24	5.14		
		238	4.33	11	5.48	223	5.86		
		241	4.53	12	5.53	226	5.41		
		244	4.59	13	5.07	227	5.35		
		245	4.72	15	5.32	229	5.30		
		246	4.46	16	5.34	230	5.42		
				17	5.51	235	4.74		
				18	4.81	236	4.78		

From the above data, it appears that there is a good general agreement between the lime needs of alfalfa on Connecticut soils and their pH values. At reactions below 4.4 pH, alfalfa is a complete failure, and less than half the yield capacity of the fertilized soils can be attained on soils more acid than 5 pH, with few exceptions. Definite responses to lime are obtained on all soils below 6 pH.

Phosphorus. The omission of this element from the fertilizer produced significant decreases in yield on both limed and unlimed soils in the majority of cases. The average for the 48 soils was an 81 per cent crop of alfalfa on the LK or LNK treatment.

There was no correlation between the total phosphorus content of the soil and its ability to produce a normal crop of alfalfa without phosphorus fertilization. There was a good general agreement between the "available phosphorus" as measured by the previously described laboratory method, and the yield capacity of the soil without the addition of phosphatic fertilizer. This is presented in Table XXII.

Table XXII. Growth of Alfalfa Without Phosphorus Fertilization.

(Available Phosphorus, in Pounds per 2,000,000 Pounds, Indicated After Serial Number of Soil.)

Practical failure (less than 50% crop)	Serious reduction in growth (50-90% crop)		Little or no response to phosphorus (90% crop or better)	
1-2	2- 5	224-15	3-33	21-10
6-2	7- 8	226-20	4-14	223-57
225-2	8- 6	227-12	5-10	229- 6
235-2	9- 5	228- 7	12-15	230-10
236-3	10-10	231- 7	13-23	232-42
240-2	11- 7	233- 2	14-31	238-10
	16- 8	234- 3	15-19	239-12
	17- 6	237- 2	18-10	244-40
	19- 7	241- 2	20-24	245-12
	22- 7	242- 2		
	23- 3	243- 5		
	24- 6	246- 7		

Potassium (Potash). The omission of potassium from the fertilizer is almost as serious as is the case with phosphorus, as shown by the results on these 48 soils, which produced on the average an 84 per cent crop on the LP or LNP treatments.

Here, also, there was no similarity between the total content of the element in the soil and the results when that element is omitted from the fertilizer. There is very little agreement between crop results and "exchange potassium" as determined in the laboratory.

TABLE XXIII. GROWTH OF ALFALFA WITHOUT POTASSIUM FERTILIZATION AND THE "EXCHANGE" POTASSIUM IN THE SOIL.

("Exchange" Potassium, in Pounds per 2,000,000 Pounds, Indicated After Serial Number of Soil Whenever Data Is Available.)

Practical failure (less than 50% crop)	Serious reduction in growth (50-90% crop)		Little or no response to potassium (90% crop or more)	
234- 75*	1-	232- 74*	2-	18-
236-148*	3-	233-155*	7-	20-
237-135*	4-	235- 90	9-	21-
243-182*	5-	238- 85	10-	22-
244-132*	6-	239- 72*	11-	24-
	8-	240- 51	12-	223- 64
	19-	241- 92*	13-	226-111*
	23-	242- 56*	14-	227-116
	224- 34*	245-131*	15-	229-214
	225-116*	246- 77*	16-	230-116
	228-166*		17-	231-240

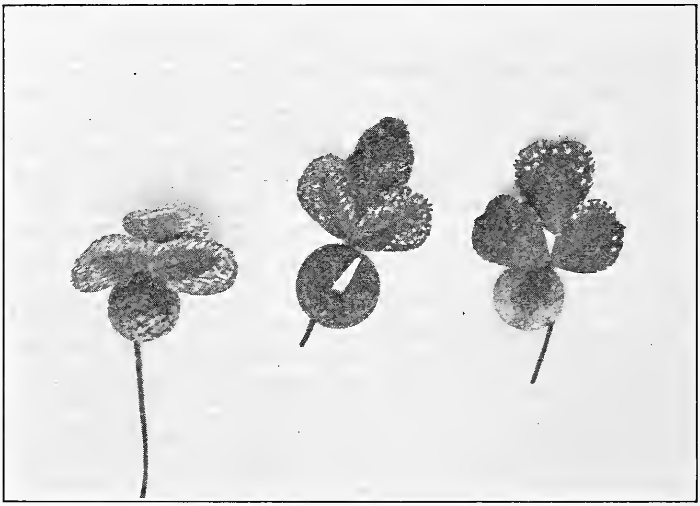


FIGURE 64. Characteristic alfalfa leaves showing spots typical of potash-hunger when grown in the LP pots of many Connecticut soils.

Soils 1 to 24 inclusive were fertilized with di-sodium phosphate as a source of phosphorus. The LP pots of these soils did not show the potash-starvation symptoms indicated by the characteristic spotting of the leaf pictured in Figure 64. This may have been due to a partial replacement of sodium for potassium in the physiological processes of the plant. All the other soils received

* Characteristic leaf spotting symptom when potassium was omitted.

no sodium in the fertilizer, and the leaf spotting was observed on many of the pots that received no potassium in the treatment.

A careful study of the data revealed no consistent correlation between fertilizer and lime requirements and the soil type, except for the lack of lime response on the limestone-derived Dover soils (Nos. 14 and 232).

Buckwheat

Buckwheat was grown in 1924 on soils 13 to 24 inclusive. It was not sufficiently sensitive to lime and nutrient deficiencies to produce significant yield differences on most of these soils, hence its use as an indicator plant to show soil deficiencies was discontinued, and the yield data is not here presented.

Lettuce

Lettuce, of the Cos or Romaine type, was grown as a test crop on 40 different soils. It proved to be a fairly satisfactory crop for indicating the lime and nutrient requirements of Connecticut soils. Yields on duplicate pots were frequently somewhat irregular, due to the failure of one or more plants to survive, but yield differences between various treatments were usually very great.

Lime. Lime was the most serious limiting factor. The crop was a total or practical failure on the majority of the soils when lime was omitted. The 40 soils produced an average of only a 28 per cent crop on NPK treatments. The results are summarized in Table XXIV.

Table XXIV. Growth of Lettuce Without Lime on Completely Fertilized Soils and Their Reaction.

Total failure (less than 5% crop)				Practical failure (5-50% crop)		Serious lime deficiency indicated (50-90% crop)	
Soil No.	pH	Soil No.	pH	Soil No.	pH	Soil No.	pH
223	4.48	314	4.66	1	5.11	3	6.26
224	3.97	315	4.45	2	4.76	4	5.08
227	3.99	316	4.65	6	5.11	5	4.94
228	4.07	317	4.21	9	4.96	8	5.27
229	4.61	318	3.93	60	4.53	9	4.96
230	4.05	319	4.22	225	4.30	10	6.58
231	3.96	321	4.20	226	4.94	11	5.48
310	4.60	322	4.95	311	5.03	12	5.53
312	4.11	324	4.31	320	4.90	58	6.24
313	4.31	325	4.11			232	6.85
						323	5.23

From the above data, lettuce appears to be even more sensitive to soil acidity than alfalfa, being a total failure at most reactions below 4.6 pH, and producing less than 50 per cent yield at reactions below 5 pH. Response to lime is significant, even with soils between 6 and 7 pH.

Nitrogen. Although the results for the average of 28 soils where there was a direct comparison between LNPK and LPK treatments, showed an 83 per cent yield where nitrogen was omitted from the treatment, gains for nitrogen were very erratic, and on ten of the soils there was a significant decrease in growth when nitrogen was applied in the form of urea. The results on soils that might reasonably be expected to show nitrogen response for such a crop as lettuce should not be interpreted as an indication that these soils might not require fertilizer or manurial nitrogen under field conditions. In a greenhouse experiment there is abnormally rapid liberation of nitrogen from the total nitrogen reserve of the soils, which is in most cases relatively high. There was no provision for leaching the soils, such as naturally occurs, hence available nitrogen not taken up by the crop tends to accumulate in the soil. In our recently revised pot experiment technique, field conditions are more closely approximated by periodically leaching the soil.

It has also been shown that the urea treatments have tended to increase the acidity of the soil. This is at least a partial explanation of the depressing effect of urea on the growth of lettuce, which occurred in every case on the unlimed pots, and in several cases even when the soil was limed.

That there is some relationship between total nitrogen content of the soil and the available nitrogen is indicated by the nitrogen response data for lettuce. Thus the following soils showing significant nitrogen response have total nitrogen contents (in pounds per acre of surface soil) as indicated:

58-1746	232-3048
60-2272	317-2840
223-1986	322-2307
225-3782	323-3773
228-3150	

All of these nitrogen contents are below the average for the state (which is 4,000 pounds per acre of surface soil).

Phosphorus. This element is a very serious limiting factor for the growth of lettuce. The average yield on LNK treatments (phosphorus omitted) was but 57 per cent. The data is presented in Table XXV to show relationship with available phosphorus tests of the soil.

TABLE XXV. LETTUCE YIELDS WITHOUT PHOSPHOROUS FERTILIZATION AS RELATED TO PHOSPHORUS AVAILABILITY TESTS.

(Available Phosphorus, in Pounds Per 2,000,000 Pounds, Indicated After Serial Number of Soil.)

Total failure (less than 5% crop)	Practical failure (5-50% crop)		Serious decrease in yield without phosphorus (50-90% crop)		Little or no response to phosphorus (90% crop or more)
310-2	6-2	315-2	1- 2	226-20	5-10
318-2	60-4	316-4	2- 5	227-12	11- 7
	225-2	317-5	3-33	228- 7	12-15
	231-7	321-5	4-14	229- 6	223-57
	311-5	322-9	7- 8	230-10	224-15
	313-4	324-3	8- 6	312- 8	232-42
	314-9	325-3	9- 5	319- 5	323- 5
			10-10	320- 6	
			58-13		

While there are a few unexplained exceptions, there is a good general agreement between the percentage yield without phosphorus and the results of the laboratory tests.

Potassium. Potassium is in general slightly more in demand for lettuce on Connecticut soils than is phosphorus. The average yield on the LNP treatment (without potassium) is 50 per cent of the LNPK yields. Results, with figures following the soil serial number, are shown in Table XXVI.

TABLE XXVI. LETTUCE YIELDS WITHOUT POTASSIUM FERTILIZATION AND THE "EXCHANGE" POTASSIUM OF THE SOIL.

("Exchange" Potassium, in Pounds Per 2,000,000 Pounds, Indicated After Serial Number of Soil Whenever Data is Available.)

Practical failure (Crop 5-50%)		Serious decrease in growth (50-90%)	Little or no response to potassium (Crop 90% or more)
1-	314- 95	3-	5-
2-	315-109	4-	7-
8-	316- 78	6-	9-
58-	317- 98	11-	10-
226-111	318-133	60-	12-
228-166	319-132	223- 64	
232- 74	320- 85	225-116	
310-141	322-166	227-116	
311-176	323-122	229-214	
312-160	324- 72	230-116	
313- 93	325-156	231-240	
		321-344	

Figures as to "exchange" potassium are not available on soils 1 to 12 and it must be recalled that these were the ones that received sodium as part of the phosphorus treatment, which may account for the lack of response to potassium of five of this group. The only correlation to be observed is the appearance of all three soils containing more than 200 pounds per 2,000,000 of "exchange" potassium in the group with 50 to 90 per cent growth without potassium treatment.

New York head lettuce was grown in the spring of 1930 in a series of fertilizer tests in .0001-acre concrete soil frames. The soil, of the Cheshire sandy loam type, is strongly acid and of low natural fertility. It was taken from an abandoned field now overgrown with broomsedge, cinquefoil and dewberry vines. Previous crops showed the following percentage yields with the omission of the various nutrients, as compared with lettuce:

	No lime	No nitrogen	No phosphorus	No potassium	Complete fert. and lime
Beets	0	70	90	56	100
Onions	5	77	76	32	100
Celery	0	79	26	71	100
Sweet Corn	75	59	94	95	100
Spinach	1	32	18	91	100
Tomatoes	88	59	28	96	100
Lettuce	13	43	23	92	100

It appeared that under outdoor conditions on this soil lettuce was less responsive to potassium than are beets, onions or celery.

The growth of lettuce in these soil frames is shown in Figure 65.

Tobacco

Tobacco of the Turkish type (selected because of its medium size, excellent uniformity and suitable habit of growth for greenhouse pots) has been grown on 51 different soils. It is a remarkably good crop to show nutrient deficiencies of the soil, since it shows both decrease in size of the plant and characteristic appearance of the leaves when an element is a limiting growth factor, or if there is some abnormal condition of the soil. This has been previously discussed by the author in a journal paper.[1]

Lime. Tobacco is apparently able to make normal growth on soils that are much too acid for many other crops. On 41 soils where there was a direct comparison between LNPK and NPK, the yield was 110 per cent without lime as compared with 100 per cent with lime. On the other hand there were certain very acid soils that were strikingly benefited by lime treatment. Such soils, notably Nos. 234, 237, 243, 337 and 340, showed an abnormal mottled appearance of the leaves when grown on unlimed pots. Analyses of the plants, chemical studies of the soil, and the similarity of growth with that which has been observed in both soil and solution cultures with the additions of abnormal concentrations of soluble manganese salts, have all confirmed the belief that this condition is due to the high soluble manganese content of these soils. This is corrected by liming, and soils less acid than about 4.6 pH have not shown this trouble. Figure 66 shows a typical plant grown on such a manganese-toxic acid soil.

[1] Morgan, M. F., Jour. Am. Soc. of Agron., 21: 130-136. 1929.

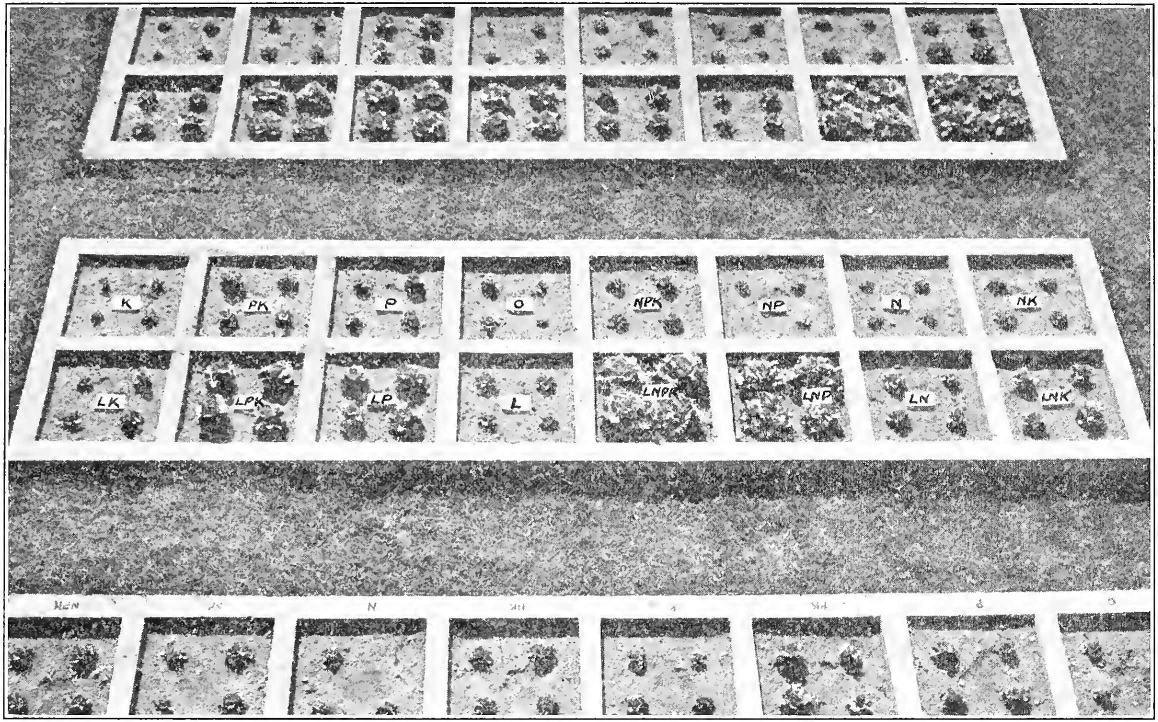


FIGURE 65. Soil frame experiment with New York head lettuce showing marked response to lime (L), phosphorus (P) and nitrogen (N), with slight response to potassium (K).

Nitrogen. While on the average tobacco has shown some response to nitrogen as grown in greenhouse pots without leaching (80 per cent yields on LPK treatments), the data is subject to the same abnormalities as for lettuce.

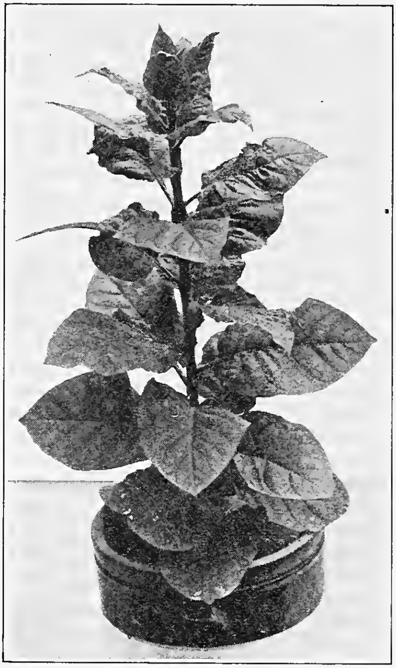


FIGURE 66. Tobacco plant grown on a very acid soil which contains a high concentration of soluble manganese.

Tobacco grown in 1930 on soils 334 to 343 inclusive, which were periodically leached, show much more consistent gains for nitrogen. This is indicated by a comparison of LPK yields on soils 310-325, none of which were leached or previously cropped in the greenhouse, with soils 334-342, leached both before and during the growing period.

Table XXVII. Yields Without Nitrogen on Unleached Soils 310 to 325 and Leached Soils 334 to 342.

Serial No.	Percentage yield without N	Total N in soil in lbs. per 2,000,000	Serial No.	Percentage yield without N	Total N in soil in lbs. per 2,000,000
310	107	3,759	323	85	3,773
311	137	3,900	324	95	5,420
312	108	3,024	325	132	2,420
313	123	4,035	334	39	4,100
314	92	5,025	335	56	4,292
315	156	8,696	336	57	5,916
316	135	5,470	337	61	3,515
317	132	2,840	338	40	3,070
318	150	9,635	339	67	5,500
319	121	5,525	340	61	4,247
320	140	4,790	341	65	3,820
321	121	8,745	342	30	3,990
322	82	2,307			

In this connection it may be of interest to present the data for the nitrate nitrogen content of the first liter of the liquid leached from soils 310 to 325, subsequent to two crops of tobacco and one crop of lettuce grown in 1929.

Table XXVIII. Nitrate Nitrogen Content of Leachate from Soils 310 to 325, February 1, 1930 in Parts Per Million.

Soil serial No.	Unlimed		Limed	
	Without N	With N	Without N	With N
310	80	300	48	470
311	70	330	56	280
312	100	260	24	270
313	74	330	36	440
314	58	260	100	315
315	100	480	164	630
316	88	385	108	450
317	84	290	100	490
318	205	410	610	940
319	155	500	470	920
320	104	410	125	610
321	108	450	350	650
322	65	200	16	85
323	60	410	30	350
324	105	450	165	490
325	100	260	120	410

The failure of nitrogen to show increase, in fact, the general decrease in yield with nitrogen treatment on this group of soils is thus explained.

Phosphorus. Tobacco is extremely sensitive to low availability of phosphorus. The average yield without phosphorus on the 51 soils growing tobacco was only 33 per cent. There is a good general agreement between yields on treatments without phosphorus and the laboratory phosphorus availability test, as shown in Table XXIX.

Table XXIX. Tobacco Yields Without Phosphorus Fertilization as Related to Phosphorus Availability Tests.

(Available Phosphorus, in Pounds Per 2,000,000 Pounds, Indicated After Serial Number of Soil.)

Total failure (less than 5% crop)	Practical failure (5-50% crop)		Serious decrease in yield (50-90% crop)	Little or no response to phosphorus (90% crop or better)
225-2	226-20	242- 2	224-15	223-57
310-2	227-12	243- 5	246- 7	232-42
318-2	228- 7	245-12	312- 8	244-40
327-1	229- 6	311- 5	314- 8	334-46
337-3	230-10	313- 4	316- 4	
339-3	231- 7	315- 2	319- 5	
343-2	233- 2	317- 5	321- 5	
	234- 3	320- 6	322- 9	
	235- 2	324- 3	336-16	
	236- 3	325- 3		
	237- 2	335-16		
	238-10	338- 5		
	239-12	340- 7		
	240- 2	341-13		
	241- 2	342- 6		

Potassium. This element showed very marked gains on practically all soils, and with few exceptions the characteristic leaf-curl of potash-deficiency was in evidence on LNP treatments. It must be noted that tobacco showed more acute potash hunger on limed pots without potassium in the treatment than on corresponding unlimed pots. This will be explained later in connection with the data on the chemical composition of the tobacco from the greenhouse pots. The average yield for 51 soils on LNP treatments was 44 per cent as compared with LNPK pots.

Table XXX. Tobacco Yields Without Potassium Fertilization and the "Exchange" Potassium in the Soil.

(Exchange Potassium, in Pounds Per 2,000,000 Pounds, Indicated After Serial Number of the Soil.)

Practical failure (5-50% crop)		Serious decrease in yield (50-90% crop)	Little or no response to potassium (90% crop or more)
223- 64	241- 92	311-176	229-214
224- 34	242- 56	315-109	231-240
225-116	243-182	317- 98	321-344
226-111	244-132	318-133	334-474
227-116	245-131	319-132	
228-166	246- 77	324- 72	
230-116	310-141	327-155	
232- 74	312-160	335-142	
233-155	313- 93	336-110	
234- 73	314- 95	337-166	
235- 90	316- 78	338- 87	
236-148	320- 85	339- 98	
237-135	323-122	340- 97	
238- 85	325-156	341-172	
239- 72	342-151	343-170	
240- 51			

Beyond the fact that all of the four soils that have shown no significant response to potassium are higher than any of the other soils in exchange potassium, there is no evident correlation between the degree of response and the exchange potassium of soils containing less than 200 pounds per 2,000,000 pounds.

Chemical Composition of Turkish Tobacco Grown in Greenhouse Pots Under Various Conditions of Fertilization and Crop Response

In order to show the effect of various combinations of lime and fertilizers upon the composition of greenhouse tobacco grown in 1929, on soils 310 to 325 inclusive, the harvested crop was sorted on the basis of treatment and apparent symptoms of crop deficiency and chemical analyses were made under the direction of Dr. E. M. Bailey, in charge of the Department of Analytical Chemistry. The results are shown in Table XXXI.

TABLE XXXI. CHEMICAL COMPOSITION OF TURKISH TOBACCO GREENHOUSE POT EXPERIMENTS.

1929, Soils 310 to 325 (Moisture Free Percentages).

Leaves and Stems

Treatment and crop condition	CaO	MgO	K_2O	Mn_3O_4	P_2O_5	N	Total crude ash
PK—yellow leaves	5.29	1.16	4.44	0.077	0.75	3.13	19.14
NK—very stunted	6.56	1.65	6.21	0.310	0.65	6.65	27.24
NP—leaves badly distorted	9.36	2.58	1.19	0.445	0.95	5.71	23.96
NK—slightly stunted	7.58	1.94	6.71	0.160	0.73	5.46	27.66
NP—leaves slightly distorted	8.29	2.06	1.58	0.300	0.79	5.75	23.30
PK—normal color	6.61	1.27	4.83	0.116	0.84	4.37	22.15
NP—normal leaves	8.13	2.49	2.05	0.180	0.81	5.27	22.72
NPK—normal plants	6.92	1.51	4.87	0.180	0.69	4.86	22.94
LPK—yellowed leaves	8.60	0.80	4.15	trace	0.71	3.96	23.67
LNK—very stunted	8.19	1.19	6.24	trace	0.58	5.83	29.48
LNP—leaves badly distorted	10.92	1.60	1.03	0.036	1.02	5.55	25.04
LNK—slightly stunted	8.76	1.13	5.04	trace	0.74	5.67	27.20
LNP—leaves slightly distorted	10.76	1.46	1.09	0.011	0.79	5.94	25.16
LPK—normal color	8.56	0.77	3.38	0.000	0.96	3.90	24.73
LNP—normal leaves	10.26	1.31	2.77	trace	0.83	5.09	25.87
LNPK—normal plants	9.44	1.01	4.40	0.014	0.81	4.98	25.62
Stalks							
PK—yellowed leaves	1.12	0.38	3.51	trace	0.43	1.05	8.15
PK—normal color	1.59	0.44	3.78	trace	0.56	1.42	9.51
NK—very stunted	...	...	...	....	0.53	4.12	22.65
NP—leaves badly distorted	3.74	1.36	2.00	0.116	0.51	2.82	11.58
NK—slightly stunted	2.37	0.75	7.73	0.014	0.50	3.04	17.54
NP—leaves slightly distorted	3.38	0.98	1.92	0.088	0.42	2.81	10.46
NP—normal leaves	2.21	0.87	3.27	0.024	0.46	2.46	10.24
NPK—normal plants	1.74	0.53	4.07	0.021	0.40	1.76	10.28
LPK—yellowed leaves	1.83	0.36	3.49	0.000	0.45	1.35	9.38
LNK—very stunted	...	...	...	....	0.43	2.48	18.61
LNP—leaves slightly distorted	3.93	0.64	1.59	0.000	0.53	2.75	9.84
LPK—normal color	1.99	0.28	2.58	0.000	0.49	1.16	8.02
LNP—normal leaves	3.02	0.50	2.50	0.000	0.48	2.20	9.85
LNPK—normal plants	2.32	0.37	3.29	0.000	0.37	1.92	9.91

This data enables one to make the following statements as to the effect of lime and increased availability of nutrient elements in the soil or added in the fertilizer upon the chemical composition of the tobacco plant:

Lime (in the form of pure magnesium-free calcium carbonate). Increases calcium and total crude ash, particularly of the leaf; decreases magnesium, potassium and manganese; has no significant effect upon phosphorus content of either leaves or stalks.

Nitrogen. Noticeably increases nitrogen, calcium and manganese content, and probably slightly increases potassium magnesium and total crude ash; has no consistent effect upon phosphorus.

Phosphorus. Very slightly increases phosphorus content of leaves, but not of stalks, if the soil is markedly deficient in this element; decreases crude ash content.

Potassium. Increases potassium content; decreases calcium and magnesium and phosphorus content; no significant effect upon manganese or total crude ash.

When other nutrients are supplied, plants not provided with:

- *nitrogen* show lower potassium, magnesium, calcium and crude ash contents, with an accompanying decrease in the nitrogen content.
- *phosphorus* show abnormally high crude ash, potash and nitrogen contents, with but slightly decreased phosphorus content.
- *potassium* show abnormally high calcium, magnesium and phosphorus contents, and strikingly low potassium content.

Oats

A crop of oats was grown after the first crop of tobacco in 1928 on soils 223 to 246. Nitrogen was then used in but one combination, the LNPK treatment. There had been a marked difference in the nutrient removal by the tobacco, and in the absence of nitrogen fertilization the growth of oats was practically in inverse proportion to the size of the previous tobacco crop. The data for soil 227 is typical:

Treatment	Tobacco gms. per pot dry wt.	Oats gms. per pot green wt.
O	1.53	111.5
P	17.58	68.5
PK	22.79	75.0
L	4.08	63.0
LP	1.17	69.0
LK	7.17	64.0
LPK	14.53	47.5
LNPK	15.23	118.0

For this reason it would be impossible to show any definite responses to lime, phosphorus and potassium. In all cases there was a very marked response to nitrogen and the growth of the untreated check plots was higher for 15 of the 24 soils than on the LPK treatments.

After obtaining these results, in subsequent trials nitrogen was added to all pots except the PK and LPK combinations. Oats was again grown in 1930 on soils 310 to 327 after a crop of sweet peppers. Again, in spite of the addition of nitrogen, diminished growth of the previous crop was the most important factor in producing increased oats yields in all cases except where there was a direct comparison between treatments without nitrogen and those with nitrogen. The only exception was the highly phosphorus-deficient soil No. 327, where the oats was almost a complete failure on treatments that omitted phosphorus.

On the basis of these results it appears that under greenhouse

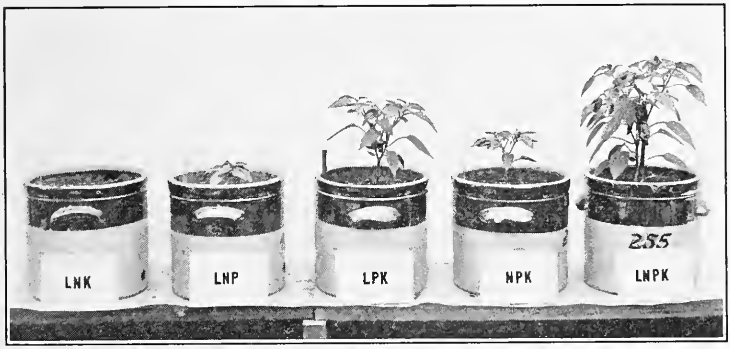


FIGURE 67. Sweet peppers in greenhouse pots of Gloucester fine sandy loam from typical unfertilized hay field in Eastern Highland, showing marked response of this vegetable to lime (L), phosphorus (P), potassium (K) and nitrogen (N).

conditions oats is a valuable crop to show nitrogen deficiencies of Connecticut soils, but is much less sensitive to lack of other nutrients, except in extreme cases.

Sweet Peppers

This crop has been grown in 1930 on greenhouse soils 310 to 327 and in .0001-acre concrete soil frames on Cheshire sandy loam at New Haven and a Wethersfield loam at Mount Carmel. The results have not been fully tabulated, but this crop is evidently an excellent one for use in indicating the nutrient deficiencies of the soils of this state. Figure 67 shows the typical growth on some of the treatments for one of the soils studied in 1930.

Preliminary observations indicate that peppers do well on most soils that are less acid than about 5 pH, but are seriously injured by more acid conditions, especially on soils that show any appreciable amounts of soluble aluminum or manganese. The crop is

less sensitive than tobacco to moderate phosphorus deficiencies, but is unable to set fruit on the more extremely phosphorus-deficient soils. On every soil the crop did very poorly without fertilizer potassium. This was also the case with nitrogen, although to a slightly smaller degree.

Carrots

This crop has been grown on soils 58 and 223 to 232. On only three of these soils, Nos. 224, 226 and 227, was there a significant response to nitrogen. However, this was prior to the adoption of the pot-leaching technique. Only four of the soils, Nos. 224, 226, 227 and 232, failed to show good response to phosphorus. These soils were the highest of the group in available phosphorus, as shown by the laboratory test. Only one soil failed to show gains for potassium. The crop was a practical failure except on soils less acid than 5.8 pH.

Other Crops

No other crops were grown on more than three different soils. The following table shows the percentage yields for these crops without the various nutrients, as grown in greenhouse pots or concrete soil frames.

TABLE XXXII. COMPARATIVE YIELDS ON TREATMENTS OMITTING THE VARIOUS NUTRIENTS.

(Percentages, with LNPK Yield = 100.)

Crop	Soil No.	Without lime	Without nitrogen	Without phosphorus	Without potassium
Sweet corn	60	50	80	30	75
	344	75	59	94	95
	346	84	58	80	81
Spinach	344	1	32	18	91
	346	84	58	80	81
Beets	58	100[1]	65	83	36
	344	0[1]	70	90	56
Onions	344	5	77	76	32
Tomatoes	344	88	59	28	96
Celery	344	0	79	26	71

[1] Soils 58 and 344 tested 6.2 and 4.8 pH respectively.

GENERAL SUMMARY

The results of the investigations of the Soils Department of this Station, which contribute to a better understanding of the physical and chemical character of Connecticut soils with respect to their suitability for crop production, their natural nutrient deficiencies, and the responses of important crops to lime and fertilizer applications, are brought together in this bulletin.

A number of terms used in soil description are defined to enable the writer to give a clearer picture of the prevailing soil conditions of the state. The effects of rock material, glaciation, climate, drainage, erosion, clearing and cultivation in producing soil differencies are also briefly discussed.

The chief differences between Connecticut soils as a group and those of other regions of the United States are explained on the basis of climatic effects in soil formation acting more slowly than usual on a rather resistant type of rock material which was almost completely disturbed during the glacial epoch.

The topographic features of the state are important in relation to soil distribution. The Eastern and Western Highlands; the Limestone Valley area within the Western Highland; the Central Lowland with included areas of trap-rock ridges; each presents a different range of soil conditions.

The more important characteristics of the groups of predominating soil types are briefly discussed, and a colored map showing the approximate location of the main areas of soils of these groups is appended to this bulletin. For practical purposes 19 groups are necessary in order to indicate soil differences of major significance.

A "key" is presented which shows the basis for classification of the soils of the state into soil series and types, depending upon color, texture, structure and arrangement of the various horizons of the soil profile and their relationships to parent rock, mode of deposition of the parent soil material, topography, drainage conditions and the occurrence of stones or boulders. Such a classification enumerates 50 named soil series, comprising 176 types and phases. A detailed soil map of the state would picture at least this number of distinct soils.

In order to show any relationships that may exist between the more important of the above soil types and the present use of the land for crops, pasture and woodland, 15 areas well distributed over the state were carefully mapped as to soil and land cover. This was supplemented by soil and farm plan maps of 190 dairy farms in eight towns of the Eastern Highland.

The present use of an area of a given soil depends not only upon the inherent quality of the soil, but upon its relation to areas of other better or poorer soils, both on the farm and in the town as a whole.

The physical factors of soil type are apparently of paramount importance in determining the present adjustment of land use to soil. These factors are: stoniness; degree and diversity of slope; texture and structure of the soil and subsoil; character of the underlying material (boulder till, gravel, sand or clay); water-holding capacity and drainage conditions of the soil.

The major groups of soil are briefly discussed with reference to the leading agricultural enterprises: dairying, orcharding, small fruits, vegetables, potatoes, tobacco, alfalfa, grass hay, corn, pasture and forest.

An estimate of the present distribution of land use of the major soil types of the state is presented.

A tabulation of the soil series occurring on the 190 dairy farms in eastern Connecticut shows a considerable degree of selection of certain soils for productive use, with the relegation of the less-favored soils to brush pasture and woodland. Thus 44 per cent of the Charlton soils are improved, as compared to only 18 per cent of the Gloucester soils. These two soil series represented 46 per cent of the entire area included in these farms.

The chemical composition of a large number of samples of surface soil representative of the important soil types of the state, has been studied in detail with respect to the following factors: organic matter and nitrogen; total and available phosphorus; total and "replaceable" potassium; calcium and magnesium; acidity, lime requirement and their relationship to soluble aluminum and manganese.

An average acre of Connecticut surface soil contains approximately:

4,000 lbs. of nitrogen
1,800 lbs. of phosphorus
29,000 lbs. of potassium

with an acidity of 5.3 pH, requiring 2.75 tons of agricultural limestone to effect its neutralization.

As compared to the above averages, which also represent the more common conditions for soils used for general crops and mowing, the tobacco soils are lower in nitrogen, potassium and lime requirement and much higher in phosphorus. On the other hand, soils from permanent pasture fields are commonly higher in potassium and lime requirement and lower in phosphorus than the average for the state.

With respect to soil type or soil series, there are few indications of a consistent superior nutrient fertility in any case. There are some differences in nitrogen and organic content that show a relationship to soil type, as would be expected from their characteristic conditions with respect to moisture and textural class. Except in extreme cases such as the very sandy Merrimac, the very heavy

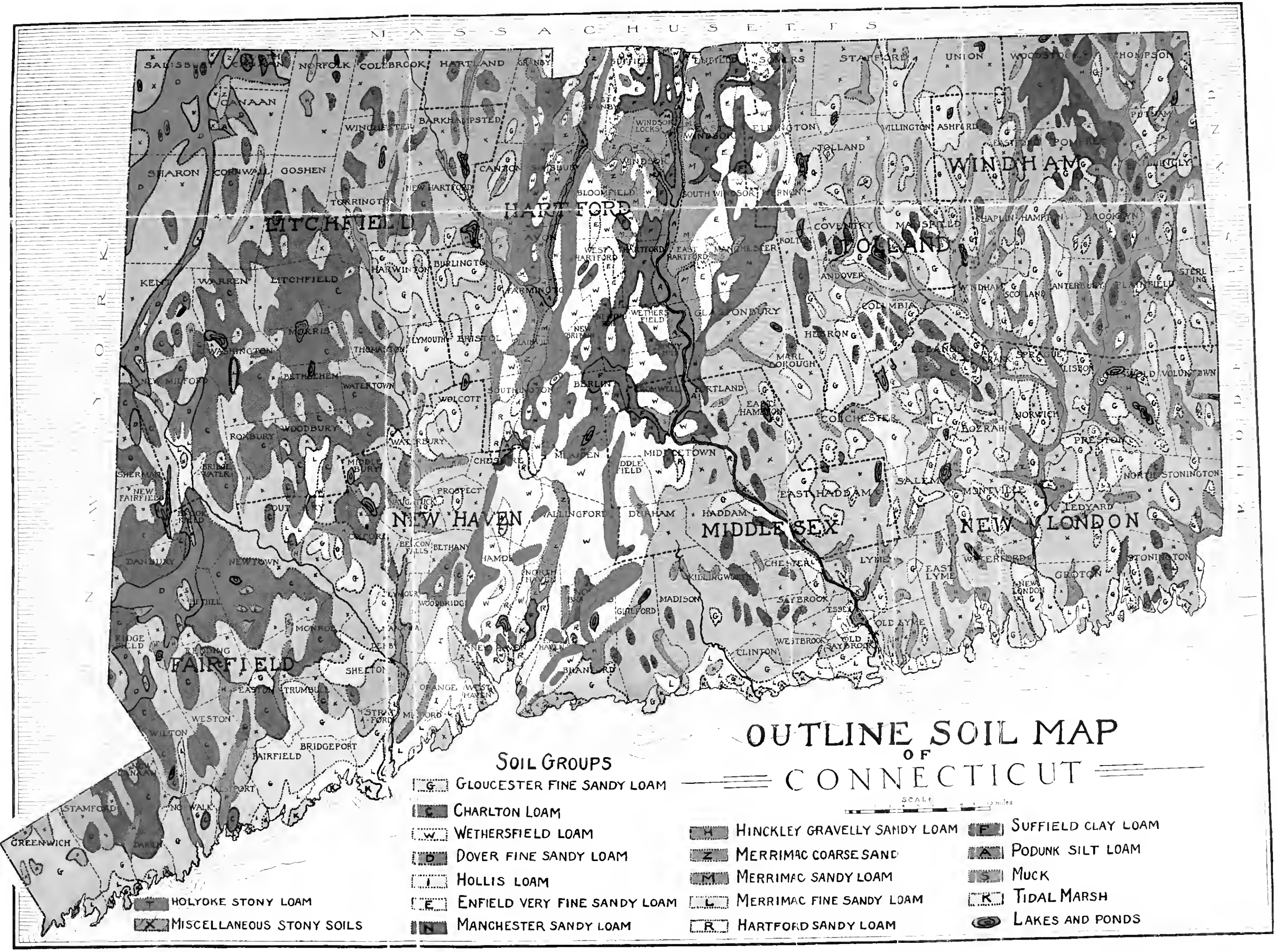
Suffield, or the poorly drained Whitman soils, under the same conditions of cultural history any one soil type of the state may show the same conditions of both total and available nutrients as any other.

A further estimate of the conditions of the prevailing soil type with respect to availability of nutrients and responses to lime, nitrogen, phosphorus and potassium, may be obtained from the results of pot experiments with 19 different soils, representing 35 soil types, and soil frames in the field representing two soil types. During the past five years the following crops have been grown on one or more of the above soils: alfalfa, lettuce, tobacco, oats, buckwheat, sweet peppers, carrots, sweet corn, spinach, beets, onions, tomatoes and celery.

The above crops vary greatly in their relative response to lime and fertilizers on the different soils. However, they all contribute to revealing the general low availability of soil nutrients and the need for lime on soils from fields that have not been heavily fertilized and limed during recent years. In general the pot and soil frame experiments show the same results as would have been predicted from the chemical studies as to soil acidity, available phosphorus, replaceable potassium and calcium, and soluble manganese and aluminum.

A greenhouse pot technique has now been adopted that permits the periodic leaching of the soil and the analysis of the leachate for such pertinent conditions as nitrate nitrogen, phosphorus, potassium, calcium, magnesium, aluminum and manganese. In the future it is hoped that this will furnish a more complete knowledge of the actual nutrient status of soils under investigation.

The greenhouse pot experiments have failed to show differences in the available nutrient supply of the soil, which are characteristic of soil types, except in the case of the naturally less-acid Dover soil. This is in accordance with the results of chemical studies. However, under field conditions, soils of two different types may be expected to show a consistent difference in capacity for economic crop production even though they are both equally deficient in plant nutrients. This is due to other limiting factors, such as poor moisture holding ability, failure to retain fertilizer applications against leaching, and unfavorable physical conditions such as irregular topography, stoniness, or excessive gravel, sand, or clay, which may exist to a greater degree on one soil than another. Both soils may need liberal fertilizer and lime applications, but on only one can the farmer obtain results that make it a profitable soil for the crop he is producing. Such factors are clearly distinguished in the classification of soil types now used in soil survey work.


OUTLINE SOIL MAP
OF
CONNECTICUT
SCALE
SOIL GROUPS
G GLOUCESTER FINE SANDY LOAM
C CHARLTON LOAM
W WETHERSFIELD LOAM
D DOVER FINE SANDY LOAM
I HOLLIS LOAM
E ENFIELD VERY FINE SANDY LOAM
N MANCHESTER SANDY LOAM
H HINCKLEY GRAVELLY SANDY LOAM
Z MERRIMAC COARSE SAND
M MERRIMAC SANDY LOAM
L MERRIMAC FINE SANDY LOAM
R HARTFORD SANDY LOAM
F SUFFIELD CLAY LOAM
A PODUNK SILT LOAM
S MUCK
K TIDAL MARSH
LAKES AND PONDS
T HOLYOKE STONY LOAM
X MISCELLANEOUS STONY SOILS
MASSACHUSETTS
LITCHFIELD
HARTFORD
TOLLAND
WINDHAM
NEW HAVEN
MIDDLESEX
NEW LONDON
FAIRFIELD